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Plastics

Dealing with the Manufacture, Uses and Potentialities of Plastic Materials

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On Joining Halves

DURING the past month we were permitted to visit one of the largest aeroplane factories in the country which turns out some of the biggest metal aircraft we have in our all-metal air fleet. In the past, so great has been the German and, indeed, world propaganda for the all-metal machine that, in common with the general public, most of us have been inclined to accept the statement that metal, especially aluminium and magnesium alloys, are the only possible raw materials for construction. In more recent years, with the improvement in our knowledge of synthetic-resin plywood combinations we are now inclined to challenge the statement; although we cannot rid our minds of a little commercial bias, practice seems to bear out our contentions that plywood, and especially impregnated plywood, has a great future.

Imagine our surprise, therefore, to find in a large corner of this metal-shaping factory a scene which reminded us of the four years' war, when the metal aircraft was unknown. Several dozen craftsmen, for that is what they were, were fitting together the halves of the fuselages of a dozen aircraft—and the halves were of plywood. The metal-mad propagandists must be grinding their teeth. The aeroplanes so made may have been merely toys, but they looked capable of giving Hitler a series of large headaches. So far so good, but we admit we wept a bitter tear at watching the men at work. To our horror, the sections of the fuselage, which was about 15 to 20 ft. long, were riveted together by rivets placed every 2 ins. along the join. Imagine the labour in driving all these screws home and in ensuring that they were flush. How much simpler the whole process would be if the plywood had been resin-impregnated or, alternatively, if the join had been made by the application of a phenol or urea resin. These resins are as strong as, and sometimes stronger than, the materials they are bonding. This has been amply proved by the plastics industry and by the aircraft industry itself in other applications. We are even looking forward to a technique when, by the application of a thermo-setting, or even thermo-plastic film, the two sections of an aeroplane can be firmly secured together by running a hot iron along the seam. We would not go so far as to recommend a plastic zip-fastener, nor so far as to proclaim foolishly the doom of the metal aircraft, but we can see clearer every day the coming impact of plastics. We certainly require a studied technique of plastics so far as it affects aircraft production.

Building the Chain

THE more chemists delve into the why and wherefore of the mechanism of plastics and their formation, the more will the moulding industry become masters of their raw material and produce better-finished goods and machines for their manipulation.

One of the most fascinating of stories we have yet listened to was told this month by Mr. A. J. Warner at a meeting of the Plastics Group of the Society of Chemical Industry, under the title of "Polymerization of Styrene." We were shown how the simple units of styrene (molecular weight 104), a liquid resembling benzene, in emulsified or pure form, joined together by heat and other means to become the solid polystyrene of large molecular weight, which we know as a white moulding powder or solid transparent blocks. We were shown the chemical process of their joining, the speed with which this was done, what controlled this speed and how polystyrenes of different molecular weights were obtained. Heat, light and accelerators all play their part. The drawing overpage shows the polymerization time curve. It was interesting to hear Mr. Warner state that he had prepared, in the absence of light and at low temperatures, a polystyrene of molecular weight of about 1,000,000! It took several years to form.

Obviously, there is an infinite variety of polystyrenes possible by altering the conditions of manufacture, for doubtless one of molecular weight of, say, 500 or even less can be made in a very short time, or one of 1,000,000 made in a very long time. The moulding powder we use is probably one of 30,000,

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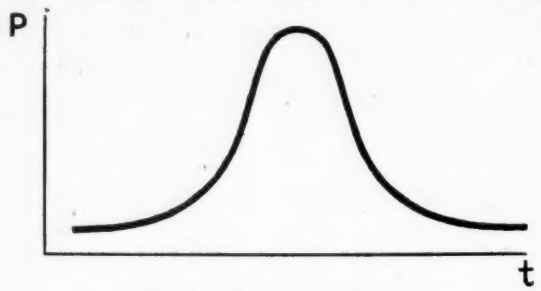
which, as physical determinations show, consists of a considerable mixture of polystyrenes, say, of about 25,000-35,000 molecular weight. In other words, the figures usually given are average molecular weights, for chemical science has not yet advanced to the point of producing a pure polystyrene of a single molecular weight. Indeed, we can see no great benefit in it, except that the viscosity of its solution would be perfectly constant. We imagine that there would be little difference in other properties—electrical and chemical—between a 500 molecular weight material, presuming it is solid, and a 1,000,000 molecular weight one, for the packing of the molecules has not changed nor has their form. They are merely heavier, slower-moving molecules of the same type.



Graph showing effect of time on the polymerization of styrene.

At the meeting, Mr. Austin Lowe raised the inevitable and important problem of price, which is admittedly high in comparison with many other moulding powders. Mr. Warner replied that difficulties of manufacture—extreme purity of styrene required, careful control, etc.—were responsible, but that polystyrene has such remarkable properties that it had become a plastic for special jobs which could utilize a high-priced material. This is perfectly true, but if Mr. Warner inferred that it could, therefore, not be employed for any but electrical jobs, he was underestimating the market. In Germany before the war, polystyrene was being used for the production of toys and a host of other knick-knacks in quantities which made the Englishman's hair stand on end. To-day, in the U.S.A., it is also being used for making high-class domestic ware, salad bowl knives and forks, "organic glass" objects of utility, etc. One clear point issues from the price question—price does not always matter. If the job or object is useful enough or beautiful enough, the purchaser, whether he is of the electrical industry or of the great buying public, will pay for it. It is high time that the plastics industry itself realized this.

Non-brittle Thermo-setting Resins. Most chemists and moulders have sighed for a new type of thermo-setting resin—a less-brittle type, one possessing properties vaguely between a thermo-plastic and a thermo-setting type. This sounds rather nonsense, but what is, perhaps, meant is a more flexible type of heat-hardening resin; this is probably a contradiction in terms. Strange mixtures, for example, the soya-phenol formaldehyde resin, have already been made, and although this seems at first sight to be a thermo-plastic and thermo-setting mixture, it is, in fact, a thermo-setting resin. Something unknown seems to have happened in the condensation. Nevertheless, attempts are being made to produce a new kind of the type described by mixing thermo-setting resins and thermo-plastic ones together. For example, it has been rumoured that certain mixtures of phenolic resins and rubberlike compounds have been accomplished, although whether the phenol has been condensed with formaldehyde in the presence of a solution of the rubberlike compound, or whether the resin has been milled on a masticator with the rubber, has not yet been divulged. No doubt either method is possible. At least it does not seem impossible to get some condensation between phenol and formaldehyde in the presence of a dilute-rubber solution, although it does not seem that the condensation would go very far. Since, too, it may be possible to select a plasticizer (that is, a solvent) which is a solid or very viscous fluid, the purely mechanical process may be employed. It seems highly probable that these two processes would produce two somewhat different materials. It would be interesting to know what happens to these mixtures in a moulding press.

Generally, such queer substances do not prove as valuable as at first appears, for certain desirable properties are destroyed. In fact, it is rare, as in ordinary life, that one can eat one's cake and still have it.

The Government Furniture Scheme. It has been suggested that many of those who have been bombed out of their homes be provided, loaned free, with certain simple units of mass-produced furniture. We hope that in formulating such a scheme the Government will approach the plastics industry to find how much it can help, and how some real co-operation between the wooden furniture and plastics industries can be brought about. From the purely moulded-furniture point of view, some progress had been made long before the war, and it would be a pity if such experience (and the moulds are still available) were not utilized. There is much to be said, too, for very wide co-operation between the plywood manufacturers and our industry for the production of simple, cheap and yet strong units. There is also, surely, enough information available now for the manufacture of chairs, for example, by pressing from impregnated sheet chairs sufficiently cheap yet strong enough to tide us over the war period.

Resins for Foodstuffs Containers. The extent to which synthetic resins of many types are being employed for the coating of food containers has been described by F. D. Farrow and T. G. Green in a paper before the Plastics Group of the Society of Chemical Industry. The types of lacquers employed (by spraying and flushing) are divided into acid resisting and sulphur resisting. For the former, i.e., fruit containers, most of the lacquers contain natural resins, but for the latter, i.e., for vegetable, meat and fish tins, the common natural-resin lacquers do not prevent sulphur staining. The main disadvantage of the oil-natural-resin lacquer are pin-holing, poor adhesion, etc. For meat tins, the old type has been superseded by phenolic-resin lacquers; that is, simple solutions of the pure resin in alcohol and hydrocarbons. Meat packs do not stick to this type, which are very resistant to sulphur. Vinyl resins, because they impart no flavour to "delicate" packs, are being increasingly employed, especially for cans containing beer, fruit juices and other beverages easily spoiled in taste or appearance.

Fungal Attack on Glyptal Resins

By H. C. BRYSON (Scott, Bader & Co., Ltd.)

Glyptal resins, that is those resins made from glycerine and phthalic anhydride, are very widely used in the paint industry, but are not normally considered of interest to the plastics moulding industry. Since, however, they are synthetic resins and since readers in the plastics industry may encounter them or similar resins liable to fungal attack, the following notes are of considerable interest. It must be pointed out that neither phenol-formaldehyde nor urea resins used for film formation are so affected.

IT is well recognized that the advent of glyptal resins presented a new standard for durability in the paint trade. For weather resistance and gloss retention they are unequalled. It has been found, however, both in this country and more especially on test fences in Florida, that some of the chief causes of the breakdown of glyptal resin films is attack by fungus. The water resistance of glyptal resins is notoriously of a low order, and this combined probably with the presence of a small quantity of free glycerol provides a comfortable home for itinerant spores. In many cases it is often difficult to recognize that breakdown has been caused by fungus. Small, hard black spots on the surface of the film may frequently be observed. These are dessicated moulds.

Report on Tests with Fungicide

In order to gain some idea as to the susceptibility of a glyptal resin to mould attack, and also with the idea of preventing it, the following tests were made:—

Two dozen small blocks of wood were taken and treated in the following fashion:—

(A) Six blocks were varnished with a solution of glyptal resin (Synolac S.B.144).

(B) Six blocks were varnished with a solution of Synolac S.B.148 glyptal resin containing .33 per cent. of a 33 per cent. solution of zinc mercury naphthenate.

(C) Six blocks were varnished with a solution of Synolac S.B.148 glyptal resin containing 0.66 per cent. by wt. of a 33 per cent. solution of zinc mercury naphthenate.

(D) Six blocks were varnished with a solution of Synolac S.B.148 glyptal resin containing 3.3 per cent. of a 33 per cent. solution of zinc mercury naphthenate.

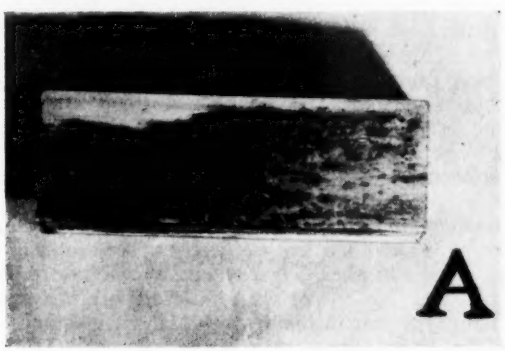
The zinc mercury naphthenate contained 33 per cent. of solids dissolved in white spirit, the metal content being 3.6 per cent. Zn. and 1 per cent. Hg. The percentages given above refer to the solution calculated on the solid (glyptal resin) content of the varnish.

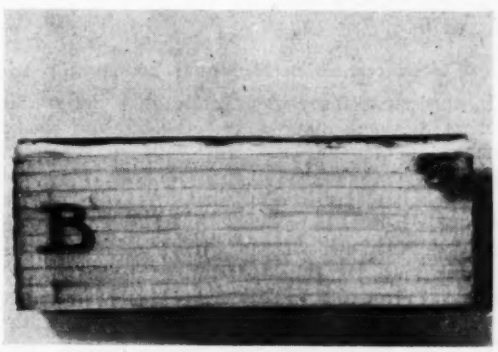
The Synolac S.B.148 glyptal resin consisted of a linseed tung oil modified glycerol-phthalic anhydride resin containing 48 per cent. of combined fatty acids. The solvent was decalin, and the drier for this varnish consisted of 1.3 per cent. of a 50 per cent. solution in white spirit of cobalt naphthenate calculated on the solid resin.

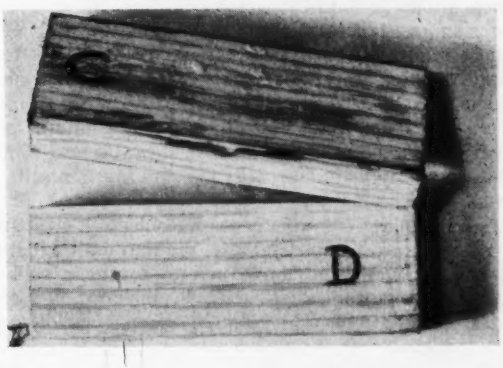
The whole of these specimens were incubated for five months at a temperature alternating between 18 degrees C. and 30 degrees C. with mixed spores of penicillium and cladusporum. The results are shown in the accompanying photographs.

(A) Has been badly attacked all over.
(B) The attack is much less severe.
(C) Has scarcely been attacked at all, while
(D) Is completely free from all fungus growth.

The specimens shown in the photographs were selected as being typical of the bulk.







Experiments on the prevention of fungus attack on glyptal resin films using zinc mercury naphthenate as fungicide. A, contains no fungicide. It will be noted that the difference between the treated and untreated specimens is very marked.

Properties of Synthetic Rubbers

There has been so much confusion in statements made regarding the properties of synthetic "rubbers" that the following notes of a paper, recently read in Detroit, is of the utmost importance, since for the first time we see the new materials compared under exactly similar conditions. Moreover, in addition to the advantages of the synthetic materials, light is thrown on some of their properties which compare unfavourably with those of natural rubber.

THERE is great interest at present in the United States of America in various types of synthetic rubber, partly because of the extreme utility of this type of product for certain applications in which natural rubber is not suitable or gives inferior results, and partly because if the country becomes involved in war there may be considerable uncertainty as to an adequate supply of natural rubber to meet requirements which are larger than those for any other single country.

For these, among other reasons, engineers and industrialists have paid considerable attention to a paper recently presented before the (American) Society of Automotive Engineers in Detroit, in which the authors, L. B. Sebrell and R. P. Dinsmore, technologists with the Goodyear Tyre and Rubber Co., give considerable data on the properties of several makes of synthetic rubber or rubber-like products. Several of the latter are now available in fairly large quantities, and others are rapidly becoming available as new plants for their manufacture are being completed. Several of the largest American rubber manufacturers are now offering and/or preparing to use in some of their own manufactured goods relatively new synthetic rubbers, and other companies, not formerly identified prominently with rubber manufacture, are making or preparing to make synthetic rubbers on a large scale. Data on the properties of several of these products were given in the paper referred to.

Differences in Molecular Structure

In the paper the authors state that the synthetic rubbers, although they possess elasticity and resilience (such as is commonly associated with natural rubber), differ very considerably in molecular make-up, hence it ought not to be expected that they will process in the rubber factory in precisely the same way as natural rubber does. Each synthetic rubber constitutes a different chemical compound, and they are similar only in superficial properties. In resistance to solvents, such as petrol, benzene and lubricating oils, some synthetic rubbers are much better than natural rubber. Some, when properly fabricated into a tyre, have shown abrasion resistance superior to natural rubber, but, in other properties, such as resistance to very low temperatures and tackiness, they are sometimes quite deficient. Thus the synthetic rubbers should be looked upon not as universal substitutes for the natural product, but as materials having special properties, which, when properly handled, will give improved results as compared with natural rubber.

After pointing out differences in molecular structure, as revealed by X-ray diagrams, the authors limit their study, as covered by the paper, to synthetic rubbers capable of vulcanization. These include Neoprene types, Buna types, Thiokol, Chemigum and Hycar. Chemigum, a Goodyear product, and Hycar, a Goodrich product, are new types of synthetic rubber, which have, in general, properties somewhat similar to Buna rubbers. All the foregoing types are compared with natural rubber.

Importance of Workability

From a processing standpoint, relative workability is indicated in some measure by the extrusion plasticities, as in Fig. 1. The values given are at 92 degrees C. Only Chemigum I and Neoprene I are really soft and workable in themselves. Others are tough and show little tendency to knit together or flow smoothly on a mill. In Chemigums II and III, Hycar OR and Buna N, especially, little can be done in further softening, except to add large quantities of liquid softeners. Severe milling or the use of peptizing agents does not effect appreciable improvement in handling. Neoprene GN and Buna S can be softened by peptizing agents, and Thiokol by small amounts of certain rubber accelerators. By far the most serious aspect of the successful use of these synthetic rubbers is their difficult processability.

For comparative purposes the authors select a tyre tread compound and a "mechanical goods" formulation, the former being loaded with 23 vol. gas black and the latter with 50 vol. of a semi-reinforcing soft black common in such formulations.

Fig. 2 shows the tensile strength of the tread series. All except Thiokol show excellent to fair tensile values compared with natural rubber. Elongation at break are shown in Fig. 3. Again, all except Thiokol show sufficient elongation to cause no great concern. Probably Neoprene GN could be further softened to give greater elongation. Fig. 4 shows the modulus at 300 per cent. elongation. This value generally reflects stiffness or resistance to deflection, and, where large variations are involved, is generally reflected in durameter hardness (Fig. 5). Aside from Neoprenes, the values compare favourably with natural rubber. Neoprene GN probably could be further softened to bring it more in line with the others.

Fig. 6, showing rebound values, reveals one of the deficiencies of synthetic rubber. Rebound is expressed as the per cent. of energy returned to a standard pendulum falling a given height, is a measure of energy absorption and a fair index of tendency for heat generation, especially when deflection cycles are repeated at a rapid rate. No one of the synthetic rubbers is equal to natural rubber in this respect, and small differences rapidly become apparent in severe service. Only by considerable development have the synthetics been made as good as here shown, but for many uses this is satisfactory or adequate.

Resistance to flexing (Fig. 7) is expressed in minutes to failure in a standard test piece of special type stretched to 60 per cent. elongation and returned to zero elongation and given a pseudo compression of 45 per cent. The compression is not actually that, since the piece is free to bend upward through this portion of the cycle. Again, the synthetic rubbers are not equal to natural rubber, although definite progress has been made in adapting them to uses where this property is a particular requisite. These flexing values are made on a standard Goodyear flexing machine. The effect of

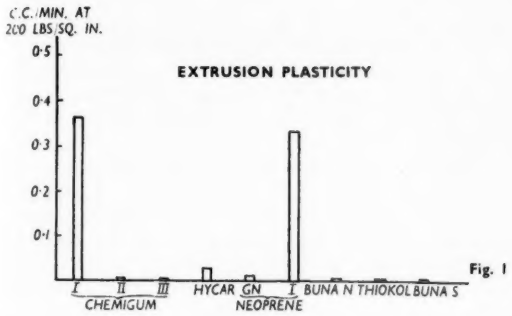


Fig. 1

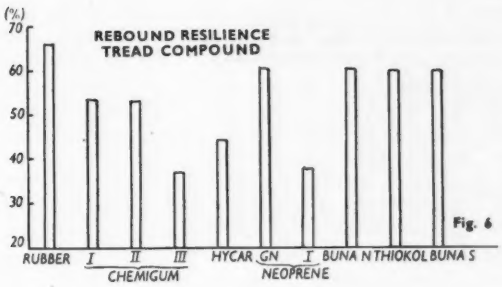


Fig. 6

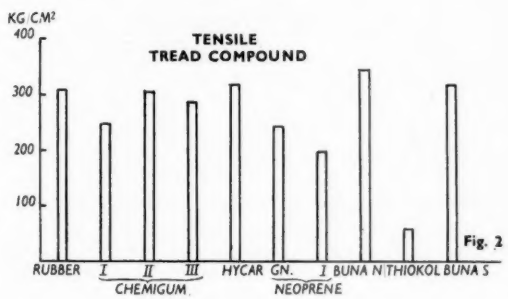


Fig. 2

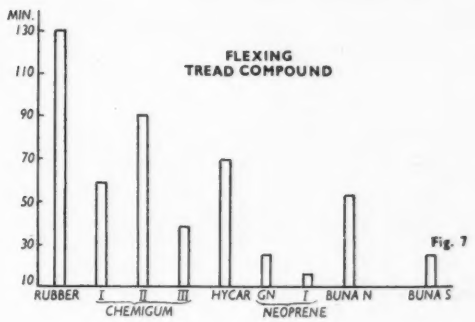


Fig. 7

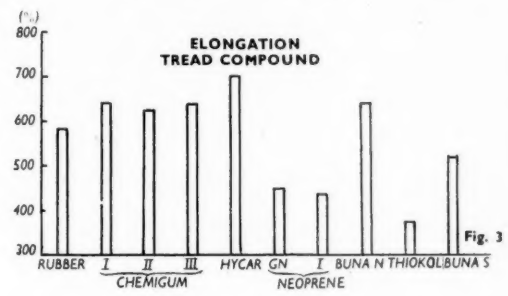


Fig. 3

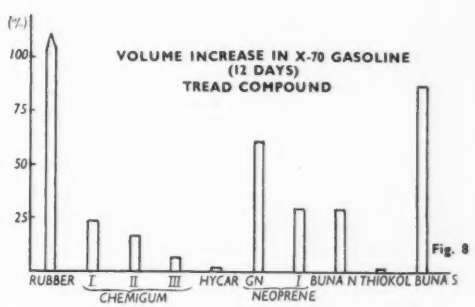


Fig. 8

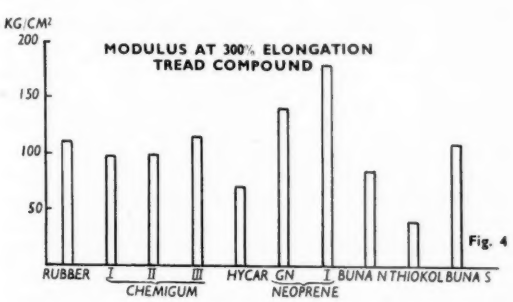


Fig. 4

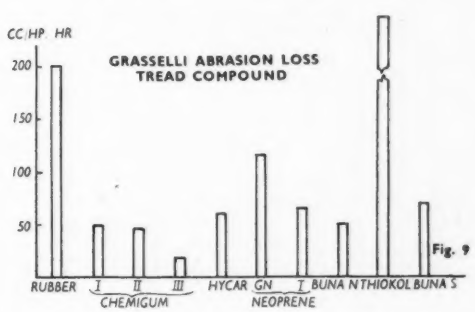


Fig. 9

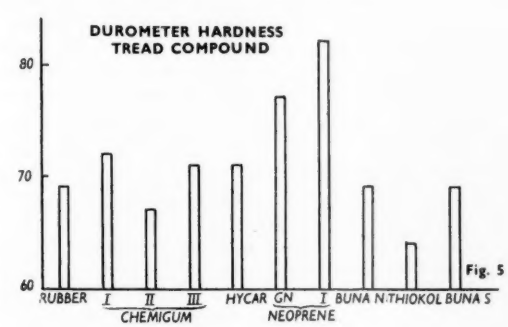


Fig. 5

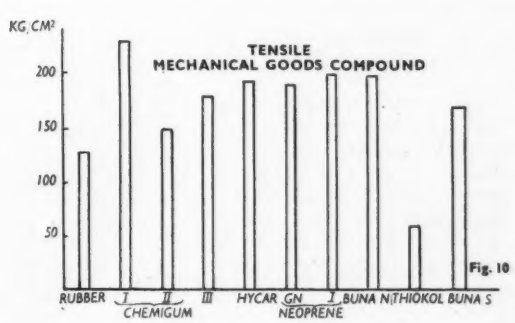


Fig. 10

Relative properties of rubber and synthetic "rubbers" under physical and mechanical tests.

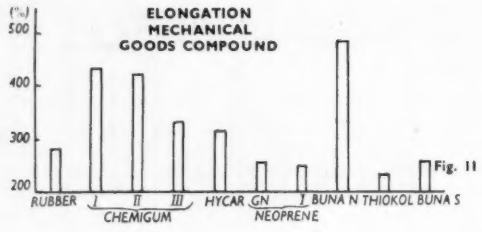


Fig. 11

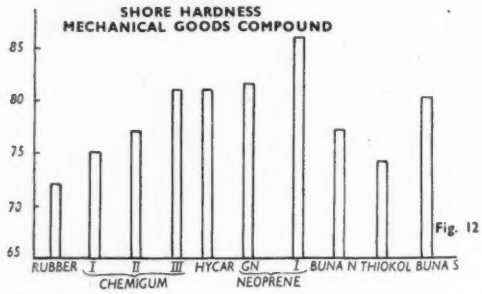


Fig. 12

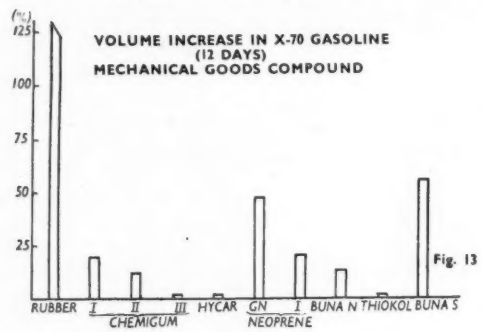


Fig. 13

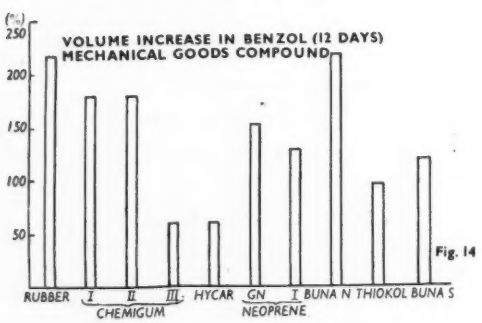


Fig. 14

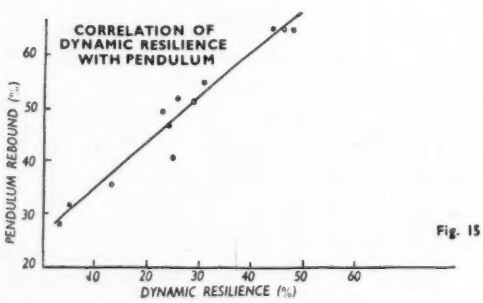


Fig. 15

Relative properties of rubber and synthetic "rubbers" under physical and mechanical tests.

permanent set, not yet definitely determined, may, if appreciable, affect the values given.

In Fig. 8 are given per cent. volume increase in a 12-day immersion in a standard motor gasoline. As expected, natural rubber is very bad; Chemigums I, II and III are progressively better. Both Chemigum III and Hycar are very good.

Although the Grasselli abrasion loss (Fig. 9) is not a reliable index of service abrasion, the degree of superiority of the synthetics over natural rubber justifies a reasonable expectation of fairly good performance for the synthetics, and this has been proved in several cases in which the synthetics show abrasion resistance in road wear of treads slightly superior to natural rubber.

Tests on Mechanical Goods

In the mechanical goods formulation, tensile and elongation measurements are given in Figs. 10 and 11 respectively. Again, many of the synthetics show quality equal to or better than natural rubber. Shore hardness (Fig. 12) indicates compounds harder than might generally be used for the purpose, but they can be softened readily, within reasonable limits, by proper softeners. The ability of the synthetic to take a given load with a minimum increase in hardness is an important characteristic. For this reason this compound was not complicated by the use of softeners. Swelling in standard gasoline (Fig. 13) shows rubber poor, Buna S (not recommended for this purpose) next, Neoprene I considerably better than GN and comparing with Chemigum I. Chemigum II and Buna N compare with Chemigum III, Hycar OR and Thiokol, the best of the series. Swelling values in Benzol (Fig. 14) show Chemigum III and Hycar best.

In respect to the tyre tread formulation it is concluded that, except for Thiokol, all may be used where service requirements are not too severe. For several services, Chemigums I and II and Neoprene GN are to be recommended, but they cannot at present be expected to equal natural rubber in the severest types of service. For other applications, where a relatively high quality of mechanical goods stock is desired, these synthetics have distinct possibilities and the added advantage of superior resistance to swelling in gasoline.

The authors describe a new dynamic test which they have devised, and give the data obtained in this test, some of it graphically, in Fig. 15. One purpose is to give such information as will enable intelligent design engine mounts and similar vibration applications. With synthetic rubbers it is especially important to have tests which evaluate elastic properties in low deformations rather than to rely on indications furnished from ultimate tensile and elongation entirely. Hysteresis loops, secured in the normal way, indicate that after 10 cycles the energy loss for a natural rubber tread stock is about six times as great as for a Buna S tread. In actual tests of tyres, however, the Buna S tread did not run at a lower temperature than the natural rubber tread. Hysteresis for various ranges of elongation showed that natural rubber is superior in elasticity and work capacity for tensile stresses below 35 kg. per sq. cm. Only above this stress is Buna S superior, hence the advantage did not appear when stocks were used in tyre treads. Similarly, other apparently contradictory test results for synthetic rubbers may later find a logical explanation. Where there is interaction of plastic and elastic properties in synthetic rubbers, it is necessary, in testing, to closely define variables which otherwise might not be so important. These include the time rate of deformation, character of deformation, etc.

Table 1.—Results of Dynamic Tests.

Test pieces: ½-in. high × ½-in. diameter.
Frequency: 60 cycles per sec.
Static load: 8% compression.
Driving force: 1.7×10^{6} dynes (Current: 2.5 amps.).

Type of Rubber	Type of Compound	Amplitude at resonance (mm.)	Dynamic modulus kg./sq.cm.	Internal friction c.g.s. units $\times 10^{-3}$	Resilience %
Natural rubber ..	Tread	.900	76	25	45
Chemigum I ..	Tread	.315	148	72	31
Chemigum II ..	Tread	.170	286	132	33
Chemigum III ..	Tread	.042	378	544	3
Neoprene I ..	Tread	.068	350	334	10
Neoprene GN ..	Tread	.325	203	69	42
Thiokol	Tread	.337	106	40	40
Buna N	Tread	.364	159	62	39
Buna S	Tread	.448	148	51	44
Hycar	Tread	.260	143	87	23
Natural rubber ..	Mech. goods	.338	151	67	34
Chemigum I ..	Mech. goods	.148	303	152	30
Chemigum II ..	Mech. goods	.128	318	177	26
Chemigum III ..	Mech. goods	.023	671	1,000	1
Neoprene I ..	Mech. goods	.046	642	368	25
Neoprene GN ..	Mech. goods	.150	315	150	32
Thiokol	Mech. goods	.171	251	132	28
Buna N	Mech. goods	.158	295	143	31
Buna S	Mech. goods	.125	356	181	29
Hycar	Mech. goods	.038	399	602	3
Chemigum II ..	20 pts. gas black	.690	86	33	40
Chemigum II ..	30 pts. gas black	.353	132	64	31
Chemigum II ..	40 pts. gas black	.165	207	137	20

Table I gives some data secured from the new dynamic test, which the authors developed. It was found that the dynamic resilience values obtained correlate rather closely with the per cent. rebound in the pendulum test. In Fig. 15, per cent. rebound is plotted against dynamic resilience for a wide variety of synthetic rubber stocks. Resilience varies over a range of 3 to 48 per cent. Rebound has a narrower range, 28 to 65 per cent. In general, dynamic resilience gives lower values and a larger spread between results for similar stocks than does the pendulum test. Calculated relative heat generation rates (Table I) show an advantage for the synthetic rubber stocks as against natural rubber, principally because of the higher values of the dynamic modulus for the synthetic rubbers. For the same force this results in much smaller deflections and hence low heat generation. Data for the last three compounds (Table I) show the controlling influence of the gas black loading on the dynamic properties. Only about half the loading in this case was required to give the synthetic rubber the same dynamic modulus as the natural rubber. For this loading the resilience is nearly as high as for the natural rubber tread stock. For the same loading, however, the synthetics gave a much stiffer and less resilient tread stock than natural rubber.

Conclusions

Above data on relative effects of loading show that, with a low loading, the properties of natural rubber may be closely approximated, and for uses where high resilience and low internal friction, with resulting low heat build-up, are required, it undoubtedly would be most feasible to reduce the carbon black loading, as indicated. It would, of course, be more expensive to use this type of compounding in a mechanical goods part than the type which has always been used for rubber. This fact illustrates forcefully, however, that synthetic rubber cannot be substituted for natural rubber on a quantitative basis nor on an equal cost basis without examining carefully the physical properties which are to result from such procedure.

THE HARDWARE CATALOGUE

By a Correspondent

ON the corner of Euston Road and Woburn Place, opposite Euston Station, you may rub your nose on the windows of what probably is the finest hardware merchant's display in the country. The hardware shop is not normally a thing of beauty, but the windows and show within the building of Nettlefold and Son, Ltd., are as fine as bronze, copper and wrought iron can make them. There are also displayed certain objects in moulded plastics.

The acceptance by the hardware trade of plastic goods is no new thing, although the range is still restricted, but as short a time as 15 to 20 years ago the plastics industry had no representative products, except in the shape of a few casein or celluloid drawer handles in rod form and small knobs. When the plastics industry got into its stride there followed a flood of door furniture, door and drawer knobs, finger plates, and so on, some few of excellent quality, some of medium quality and a veritable spate of the cheapest rubbish that was ever turned out of a press.

Looking back on those bad days, we can safely say that some of the newly fledged moulding factories "tried to pull a fast one" over the buying public. Not that they alone were at fault. They were ably seconded and abetted by a host of cheap-jack distributors that crawled the earth. The final result was that the reputable hardware merchant soon realized that the cheap plastic object was often useless for his purpose. Luckily for the plastics industry, he also realized that there was a sound core of moulders who knew what they were about and refused to make low-quality material. That core still remains and is, indeed, growing steadily larger with the realization that high quality pays.

Nettlefold and Son, Ltd., is in the first rank of hardware merchants and have paid our industry the compliment of a special catalogue devoted solely to plastic goods. These are, in the main, confined to door furniture, as it is called. Lock handles and, surprisingly, book cases, finger plates, door pull handles and drawer pulls, combined lever handles and lock sets are profusely illustrated in this 12-page catalogue. Some are moulded from phenolic and urea resins, some are cut from cast resins, casein and what this trade calls synthetic glass—probably cast phenolic or acrylic resins. On the whole, this is an illuminating document, and will encourage our industry.

Moulded ball-float for cisterns.

The latest encroachment of plastics on this industry is about to be included. It is a 4½-in. ball-float for water cisterns, moulded of special phenolic resin in two sections with a metal insert to receive the actuating bar. The lid is a special shrunk-on fit and is sealed inside and outside with a sealing compound. It is extremely robust and the manufacturers, R. Cartwright and Co., Ltd., of Fleet Street, Birmingham, inform us that this apparatus has been thoroughly tested out under 3 ft. of water over prolonged periods without leakage. We congratulate this concern on an excellent job.

C

ADHESIVES and CEMENTS

In our January and February issues, the author completed the sections under phenolic and urea-formaldehyde resins in adhesives and cements. In these pages he deals with some of the nitrocellulose and cellulose acetate types, whilst in succeeding issues he will describe the compounding and use of polyvinyl and polyacrylic resins for this purpose.

By
E. E. HALLS

Nitrocellulose Base Cements and Adhesives

NITROCELLULOSE forms the base of many adhesives and cements, and merits consideration on account of its ease of application and rapidity of drying. Proprietary cellulose cements, in a range of consistencies, are available. They consist of solutions of nitrocellulose, with added resinous matter to improve adhesion, and plasticizing agents to impart flexibility, the whole being in a balanced solvent mixture. Table 5 covers typical compositions.

Often it is more convenient to prepare nitrocellulose adhesive solutions on the site, and many are produced from virgin celluloid scrap dissolved by means of a

Table 5.—Characteristics of Proprietary Nitrocellulose-Base Adhesives or Cements.

Sample No.	16	17	18
Source	I	J	K
Chemical			
Volatile Spirit (loss in weight, 3 hours at 110°C.), %	64.5	78.5	76.4
Total Solids (nitrocellulose resins and plasticizers), %	35.5	21.5	23.6
	100.0	100.0	100.0
Physical:			
Viscosity at 25°C., centipoises	450	Over 5,000	Over 5,000
Specific Gravity at 25°C.	0.887	0.895	0.904

mixing machine in a suitable solvent, acetone or amyl acetate, or a mixture of these being most suitable. Table 7 gives formulæ actually employed; the inclusion of amyl acetate is to slow the rate of drying.

A straight nitrocellulose solution cited specially for sticking paper to aluminium comprises the ingredients shown in Table 8.

A heterogeneous type of paste, comprising the aqueous starch of dextrin adhesive mechanically mixed with nitrocellulose adhesive, has its uses and is surprisingly effective. The theory of its success may be attributed to two "dries," which occur simultaneously, but independently, side by side. The film obtained is "uniformly heterogeneous," the starch and nitrocellulose particles having dried out independently, thus eliminating shrinkage stresses in the film, with the result that adhesion is superior to that provided by either adhesive alone under otherwise similar conditions.

The various nitrocellulose cements fulfil a multitude of purposes. They are most efficient when both the materials to be joined are absorbent, e.g., fabric to wood, paper to wood. When one is metal, however, sound adhesion in many cases is possible. All of the compounds in Table 5 have been employed for securing felt to lacquered or enamelled metal and to bare metal. In the latter case the junction is satisfactory if the metal be rigid, and is improved by abrasive blasting or some similar roughening process.

For small labels to be secured to metal the writer prefers one of the celluloid solutions given in Table 7. This applies to bare or to lacquered and enamelled metals. No. 21 has been found to give very good service on both aluminium and tinplate, which yield, perhaps, the worst surfaces encountered in practice. Further to protect against the probability of labels

Table 6.—Characteristics of Starch or Dextrin-Base Adhesives Suitable for Compounding with Nitrocellulose Adhesives.

Sample No.	19	20
Source	L	M
Chemical:		
Starch base, %	37.8	40.8
Water, %	62.2	59.2
	100.0	100.0
Ash on Incineration, %	0.27	0.88
Reaction	Faintly Alkaline	Faintly Alkaline

Table 7.—Typical Compositions of Readily Prepared Cellulose Adhesive Solutions.

Sample No.	21	22	23
Composition by Weight, %:			
Celluloid, virgin scrap, high viscosity	10.0	25.0	10.0
Acetone	90.0	75.0	45.0
Amyl Acetate	—	—	45.0
	100.0	100.0	100.0

tearing up from corners by mechanical handling, a spray or brush coat of top lacquer is useful.

Again, the writer prefers the acetone preparation No. 21 in Table 7 for securing cellulose acetate to itself or to other materials, in preference to many proprietaries put forward for the purpose. Acetate film up to 0.005 in. (0.127 mm.) thickness, for example, can be secured to the metal in this way, but it is advantageous, if practicable, to roughen the metal. For greater thicknesses of acetate, the metal must be of sufficient gauge to be rigid, then, with sand- or shot-blasting, this cement will give a serviceable joint.

An interesting nitrocellulose cement, referred to commercially as "cold solder," proved to be a nitrocellulose solution containing 1.5 per cent. of aluminium powder. The action of this ingredient would be to "break" the continuity of the film, control shrinkage and so improve adhesion.

Metal to Metal

The joint appeared to be very strong when attempts were made to pull it apart in the plane of the joint, but when bent to about 15 degrees at the join, was easily separated.

Wood to Wood

Fairly strong joint.

Glass to Glass

A broken beaker was mended with the compound and water boiled in it for several hours. The joint was watertight, but the cellulose in contact with the hot gauze over the burner decomposed.

As an example of the use of the starch/cellulose adhesive may be cited the application of a 50/50 by weight composition of either of the starch adhesives shown in Table 6 with cellulose cement No. 17 or 18, Table 5. This mixture is used for fixing large paper wrappers or small labels to metal in any condition. If a coat of top lacquer be applied a thumb-nail proof junction is secured (Table 14).

For securing cellulose nitrate base materials to themselves, e.g., securing foil, cementing mouldings or plastics, solvent alone is sometimes used. The mating surfaces are moistened, pressed together and held under pressure for a short period. A range of solvent mixtures for this purpose is given in Table 10A.

A nitrocellulose adhesive solution in acetone is used for cementing the strands of cellulose acetate yarn

Table 8.—Nitrocellulose Solution for Securing Paper to Aluminium.

Composition per cent. by Weight:	
Collodion	7.0
Ethyl Ether of Ethylene Glycol	14.0
Butyl Alcohol	5.0
Methyl Acetate	34.0
Industrial Methylated Spirit, 64 O.P.	40.0
	100.0

Table 9.—Cellulose Acetate Base Adhesive Solutions.

Sample No.	24	25	26
Composition by Weight, %:			
Cellulose Acetate Powder	5.0	3.0	8.0
Celluloid (High Viscosity Virgin Scrap)	—	2.0	4.0
Acetone	95.0	95.0	66.0
Diacetone Alcohol	—	—	22.0
	100.0	100.0	100.0

coverings of small electrical coils. The dope is applied by dipping and draining, and a formula used is as under:—

Acetone	80 per cent.
Cellulose cement (sample No. 17 or 18, Table 5)	15 per cent.
Castor oil	2.5 per cent.
Tri Cresyl Phosphate	2.5 per cent.

Dipping is for 30 seconds, and after air-drying for 12 hours a moisture protective coating of nitrocellulose cement (e.g., material No. 17 or 18, Table 5, thinned 50/50 with acetone) is brushed on.

Several concerns have specialized in a range of nitrocellulose base cements and adhesives, developed with specific types of application in view. Cellon, Ltd., observes that the adherence of metal to metal depending solely on an adhesive applied between the two surfaces is unusual, and it is only in a few cases in which metallic foils of thickness up to around 0.005 in. (0.13 mm.) have given satisfactory results with adhesive alone. For such purposes Cerric clear adhesive D.3639 has been employed, either allowing the surface to air dry under light pressure, or utilizing the thermo-plastic nature of this adhesive, allowing the surface to air dry

Table 10A.—Solvent Adhesives for Nitrocellulose Plastics.

(27)	Dibutyl Phthalate	100 parts
	Butyl Acetate	50 parts
	Ethyl Acetate	50 parts
(28)	Tri-cresyl Phosphate	5 parts
	Monoethyl Ether of Ethylene Glycol	100 parts
	Acetone	5 parts
(29)	Tri-cresyl Phosphate	25 parts
	Ethyl Oxybutyrate	100 parts
	Ethyl Alcohol	25 parts
(30)	Diethyl Phthalate	50 parts
	Dioxan	100 parts
	Ethyl Alcohol	50 parts

before being placed into contact, and then giving light pressure and heat of the order of 120 degrees C. Such joints are good and at least equal in strength to that of the foil itself.

Cerric Adhesives in Aircraft Construction

For greater protection against rusting or corrosion, and particularly in connection with magnesium alloys, a chromated adhesive of similar type is advantageous. Cerric adhesives C.3791 and C.36100 are of this type, containing metal chromates in different concentrations and types. The patented Cellon strip-sealing process, fully approved by the Air Ministry, may be mentioned here, as this process consists essentially in the application of a thin metallic strip over a surface which requires levelling or smoothing, or otherwise to be sealed.

For this purpose the strip is applied already coated on one side with a chromated thermo-plastic adhesive, and, having been laid on the surface, is secured by the application of a special thermostatically controlled electric iron, giving light pressure and a temperature of 115-120 degrees C. This process is applicable not only to metal surfaces, but also to wood, pressed board, etc., and is widely used in a number of industries.

In connection with metal-to-metal adherence, jointing compounds serve not only to prevent electrical contact, but also in some measure assist in the adhesion between the surfaces in contact. Cellon, Ltd., manufactures a range of various types of jointing compounds, which include Cerrex C.37143, which complies with the requirements of A.M. specifications DTD369 and 469A. There are also more rapid-drying types.

Metal-to-fabric Adhesion

Fabric-to-metal adherence has caused considerable difficulty in the past, particularly in connection with aircraft, but here Cerric clear adhesive D.3639 has been widely adopted for the purpose, not only by constructors, but by the Air Ministry. It is usual practice to apply a coat of the adhesive by brush or spray to the metal, a further coat being applied over the fabric. This material air dries quite satisfactorily, but further improvement can be effected by smoothing down finally

Table 10B.—Solvent Adhesives for Cellulose Acetate Plastics.

(31)	Triacetin	100 parts
	Methyl Oxybutyrate	25 parts
	Methyl Acetate	25 parts
(32)	Dibutyl Tartrate	100 parts
	Ethyl Lactate	20 parts
	Diacetone Alcohol	20 parts
	Ethylene Dichloride	15 parts
(33)	Dimethyl Phthalate	5 parts
	Monomethyl Ether of Ethylene Glycol	90 parts
	Methyl Acetate	5 parts
(34)	Monomethyl Xylene Sulphonamide	100 parts
	Ethyl Lactate	50 parts
	Ethyl Alcohol	50 parts
(35)	Paraethyl Toluol Sulphonamide	25 parts
	Dioxan	100 parts
	Acetone	10 parts

with the electric iron already mentioned in connection with the strip-sealing process for dealing with the fabric edge has been found invaluable.

For very small industrial jobs a special adhesive, Cerric 2D.444, is of notable interest, as it provides joints which quickly air dry and become quite water and oil-proof. A lower viscosity-type adhesive, Cerris D.444, is also available for joints between wood and fabric to wood, and for a variety of porous surfaces giving quick-drying and tough joints.

Another adhesive which has found considerable application is Cerric non-drying adhesive D.37195. This is a low-viscosity clear liquid, which quickly air dries to a permanently tacky condition. It is, like the other adhesives mentioned, insoluble in water, petrol and oil, and may be used for sticking porous surfaces, such as paper, fabric, etc.

Cellulose-acetate Base Products

For securing cellulose-acetate film to itself or to plastics, such as laminated bakelite, solvent alone is often specified. Thus, acetone is used in the winding of small coils where acetate provides the electrical insulations. Some workers prefer one of the solvent mixtures given in Table 10B. A proprietary cement

Fig. 1.—Pressing from natural silk coated with cellulose acetate.

marketed for securing acetate film insulation of small electrical coils has been examined and found to consist of methyl cellosolve. The following characteristics were recorded:—

Volatility, 3 hrs. at 110 degrees C.	100 per cent.
Boiling range	98 per cent. between 121-124 degrees C.
Specific gravity	0.967 at 20 degrees C.
Viscosity at 25 degrees C. ...	1.6 cps.
Corrosion on copper (24 hrs.)	nil

Again, others prefer an adhesive solution, and, in fact, this is more effective when thickness of acetate exceeds something of the order of 0.005 in. The acetone solution 21 in Table 7 is advocated and 22 where a more bodied material is desired. On the other hand, for those who require acetate-base materials, a range employed is given in Table 9. From this, 25 or 26 is employed as a stiffener for jap silk prior to pressing simple forms. For example, jap silk 0.0015 in. to 0.0025 in. in thickness is coated by spraying the stretched silk in a frame on both sides with the adhesive. Sufficient is applied to give a thickness of dope film, expressed by weight on the basis of the finished product, 15 to 45 per cent., according to the object to be fabricated. The material is blanked in an ordinary press tool. The blank is then formed and pierced in a tool with clearance between punch and die to suit the thickness of the blank. The forming is performed cold with 74 OP methylated spirit as lubricant. The article is then transferred to a shaped fixture to hold it in position and baked to set it for a few minutes on a hot plate. The temperature of the latter is adjusted to give a work temperature of about 100 degrees C. Finally, the periphery is trimmed. Small cups shown in Fig. 12 are made in this way from 0.0020-in. silk doped to 35-40 per cent. and overall thickness 0.0025 in. Such cups are used in telephone transmitters as carbon chambers.

Ethyl Cellulose Adhesives

Mention under this section may be made of ethyl cellulose, which, being an ether, is very stable and shows no tendency to hydrolyse. It is claimed to be very suitable for adhesive solutions, although, perhaps, more exploited on the Continent than in this country. This younger member of the cellulose ether family has shown great possibilities because of its toughness, compatibility with resin-plasticizer mixtures and ready solubility in a wide variety of organic solvents. Thus, by proper selection of resin and plasticizer it is possible to make adhesives of the hot-melt type or adhesives with a solvent base, depending upon the type of application.

The hot-melt type can be satisfactorily formulated with a content as low as 8 per cent. ethyl cellulose, the balance being resins and plasticizers. Resins suitable for this use are dewaxed damar, kauri, certain types of phenolic resins and ester gum. Selection of plasticizer is primarily dependent upon compatibility of that plasticizer with ethyl cellulose, although for many uses such qualities as colour, stability to light and heat, and freedom from odour and taste are of the utmost importance. Four plasticizers are available that meet all these requirements; these are diamyl, diethyl, dibutyl and dimethyl phthalates. A favourable characteristic of hot-melt adhesives is the unusual rise in melting-point resulting from the addition of ethyl cellulose.

It has also been observed that ethyl cellulose gives an effective action in diminishing the tendency of waxes and resins to crystallize. These adhesives have been used for the lamination of "Cellophane" to paper, cellulose acetate to cellulose acetate, "Cellophane" to "Cellophane," metal foil to "Cellophane," metal foil to paper, cardboard to cardboard, cloth to cloth, and paper to paper. It is claimed that formulations of this type show great adhesion at freezing point, resist heat and withstand a test for bonding for at least one hour when the lamination is subjected to a deadweight of 3 grams per sq. cm. at a temperature of 45 degrees C.

For many types of work it is found more practicable to apply formulations made with solvents rather than to depend on heat. As ethyl cellulose is soluble in a wide variety of organic solvents, a suitable type may be chosen from the standard lacquer solvents or from the aromatic coal-tar solvents. Ethyl alcohol dissolves 16 per cent. by volume of ethyl cellulose, and this solution can be made perfectly clear with the addition of toluol. Butyl alcohol, mixed with xylol, also gives a clear solution. Other acceptable solvents are amyl alcohol, amyl acetate, butyl acetate, ethyl acetate, ethyl lactate, acetone, and many other of the usual cellulose nitrate solvents; these give good solutions with from 5 to 16 per cent. ethyl cellulose.

(To be continued).

Plastics and Powder Metallurgy

By H. W. Greenwood

The author, who is one of the best known of metal powder technologists in the country, gives in the first article of this series some general notes on the desirability of altering some of the properties of plastics by the addition of metal powders and the trend which such changes may take. There is a general agreement that examination of the many problems involved is very necessary.

THE field of plastics to-day is large but restricted—restricted by the inherent properties of the plastics themselves. In many directions these properties are a positive advantage; one can think of beauty, resistance to breakage, non-conductivity of heat and of electricity, chemical resistance, etc. Yet certain of them, in special circumstances, can prove to be disabilities, and when that is so these properties will militate against extending the field of usefulness of plastics.

So far the properties of plastics as we know them to-day have been acclaimed as lending themselves to exploitation in specific directions. This is only another way of saying that the development has followed the line of least resistance and that uses have been found for the plastics produced. This has been much more truly and more frequently the case than the planning of a plastic with certain specific characteristics first, and producing it afterwards.

Possibilities of Widening the Field of Plastics

Consideration along these lines would lead us to ask what properties would be called for supposing it were desired to materially extend the field of plastics, and are there clear indications of directions in which expansion would occur if such modification of properties can be achieved? The answer is at once positive and affirmative. The lack of certain properties is a definite bar to the utilization of plastics or to their widespread use.

The very properties that are so advantageous in certain directions are those which prevent exploitation and development in others. The fact that plastics are non-conductors of heat renders them of special value for many purposes where a heat insulator is essential, e.g., handles and the like. Equally it is a disadvantage when the use of plastic bearings is concerned, and must be overcome if any large development of plastic bearings is to occur.

Changing the Dielectric Properties

The dielectric properties of plastics is another example; plastics at present are essentially insulating materials, and while this means an extended field of usefulness in one direction in the electrical industries, it quite definitely rules out many other possibilities. The use of metal powders as additions to plastics can convert them into conductors of heat and/or electricity, and with the necessary study of conditions can lead to new developments in plastics. Hardness is another property which can be materially influenced by additions. At present all plastics can be grouped among moderately soft materials. As a result they are not thought of as possibilities in certain directions, particularly in various branches of engineering. But the addition of metal powders can confer hardness, and, what is even more important, can confer a hardness that can be controlled within very wide limits by choosing metals of suitable hardness. This immediately offers possibilities previously unthought of.

This does not mean that the addition of metal powders to plastics is so simple that a child can undertake it. It does mean that it will be worth while investigating the conditions under which metal powders and plastics can be most effectually wedded to obtain a particular result. From the plastic side it must not be forgotten that the plastics in common use to-day all enjoy more or less the property of being chemically inert once they are fabricated. This inertness is, however, a variable and is more pronounced in some plastics than in others; for example, the polyvinyl resins. Just in the same manner metals differ in their reactivity, and as it is obvious that a fairly wide range of combinations are likely to be required if the fullest range of plastic-metal combinations is to be available, quite a good deal of investigation will be called for in order to determine the most favourable conditions and materials for effecting any particular combination.

Another matter of considerable interest is that the effect of metal powder addition does not necessarily follow the usual rules that the greater the weight added the greater the effect. Another factor enters, namely, density or specific gravity, and thus it is possible that by substituting one metal for another an almost equivalent effect can be obtained by the use of about half the weight of metal, bulk playing a large part. Thus in increasing the conductivity of plastics a certain effect can be obtained by the addition of 10 per cent. weight of copper powder.

Aluminium v. Copper Powder

If aluminium be substituted for copper almost the same effect can be obtained by the addition of only 5 per cent. by weight. This does not mean that the conductivity of aluminium is double that of copper. We know that, in fact, it is less than copper, but the density of aluminium is only one-third that of copper, hence weight for weight it has three times the bulk. and this is the important factor. Obviously there are many other similar conditions to be realized when the combining of metal powders and plastics comes to be considered, and it is essential that these relationships be explored adequately, so that once development work is undertaken it can proceed with a minimum of interruption due to snags which should have been foreseen and eliminated earlier.

Density is not the only property of metal powders that is likely to introduce somewhat unexpected factors into questions relating to their utilization. There is also the much higher reactivity due to the tremendous surface which a powder, and particularly a powder of small particle size, offers to either the atmosphere or any other phase with which it comes into contact.

There is also the character as well as the size of particle to be considered, whether it is of regular or irregular shape, of spongy or of solid constitution. There is also the question of oxidation and the effect

(Continued on p. 59.)

The Plastics Effort in War Emergency Conditions

THE tentacles of plastics are firmly driven into many fields of industry. Fundamentally, plastics belong to the chemical industry, by virtue both of the majority of raw materials involved and of the plastic base manufactured. Ultimately its products find their way into practically all trades, including all spheres of the engineering, building and domestic industries. During the past 20 years or so, during which remarkable progress has been made, much has been unobtrusively established that under normal conditions was not appreciated but which under emergency conditions has proved to be an invaluable asset. This hidden wealth embraces materials, labour, plant, methods and techniques, as well as the technical knowledge associated with all these. Materials include heavy and fine chemicals, fillers and pigments both natural and synthetic, and papers, textiles and fabrics. Labour comprises all types, but much of it is skilled and very little unskilled. On the technical side it includes all categories of chemists and chemical engineers, and many mechanical and electrical engineers. On the operating side it embraces the classes of chemical labour that have to be familiar with the handling of corrosive, poisonous and inflammable materials, and with processes entailing pressure, vacuum, distillation, etc. Tool makers, machinists and press operators are enlisted on the engineering phases. The range of plant is evident, covering high-pressure and high-vacuum processes, and corrosion problems from the chemical aspect, light and heavy presses, with heating and cooling, manually or automatically operated, capstans and automatics, and milling and sawing machinery from the engineering angle. Methods and techniques entail all those of applied chemistry and modern engineering, and incorporate "flow line" production on a mechanized basis whenever appropriate. All this signifies that the plastics industry possesses a wealth of knowledge and resources distributed far and wide, and forming not only the nucleus for a much expanded activity that can rapidly be put into effect. Again, quite a fair proportion of the normal plastics effort is engaged in luxury and decorative work, or for the packing trades, and therefore the facilities of these sections of the industry become immediately available for work of a more pressing nature. The first debt to plastics, therefore, is for the creation of knowledge, facilities and trained personnel.

Diversity of Properties of Plastics

Plastics in themselves offer a range of materials in a variety of forms, and a combination of these possibilities with the diversity of desirable properties enables a selection to be made with predetermined confidence in suitability to fulfil specific service requirements. Granted, they have their shortcomings, but an extraordinary fact is the "definite-ness," if one may be excused the term, concerning their suitability or otherwise for particular applications. This precise statement applies to the whole range of plastics. Mechanical properties of tensile strength or impact, crushing or compression; physical qualities of moisture absorption, dimensional stability, resistance to heat, softening, charring or burning temperatures; chemical properties with respect to behaviour under the influence of fume or vapour, solvents or solutions, solid chemicals and pastes, oils and waxes: all these are known to a reasonable degree of accuracy. In consequence, a material is known to be suitable or unsuitable before it is accepted, or to be a borderline case for adoption or otherwise, according to whether the circumstances justify a field trial or not.

What Plastics Offer to Industry

Broadly speaking, plastics can generally offer the following unique qualities:—

1. Stability, promoting long service life.
2. Inertness, signifying freedom from corrosion problems, health hazards from the user's viewpoint, and lack of change in appearance and configuration.
3. Electrical insulation, rendering them the base of practically all modern dielectrics.
4. Versatility respecting form, sheet and strip, rod and tube, tape and sleeving, mouldings and pressings.
5. Amenability to common engineering fabrication processes of sawing and guillotining, milling and turning, slotting and threading, blanking and pressing.
6. Generally, no protective finish required, and in most cases no decorative finish involved.
7. Low specific gravity when compared even with the magnesium light alloys, and generally a good strength/gravity ratio when compared with the metals.

These merits promote wide adoption under emergency conditions with satisfaction at knowing serviceability of the selected types will be sound, and that adaptability enables their introduction into existing designs with the minimum of modification. The field can be best demonstrated under four headings:—

1. Fulfilment of the needs of electrical insulation.
2. Mouldings meet the demand for reproducibility.
3. Sheet stocks for panellings and other forms for mechanical needs.
4. Glass substitutes.
5. The answer to specifically severe conditions of mechanical strength, chemical service, food purposes, fire resistance, heat and oil resistance.

1. Fulfilment of the Needs of Electrical Insulation

The war is one of mechanization and communications; it is a battle of scientists working to prevent the old-time mass-slaughter conception of war. Telephone, telegraphic and radio communications are a first essential; electrical devices for signalling and for all forms of remote control are war equipment; accuracy, constancy and long life under rough conditions, rough mechanically as well as by virtue of weather exposure, are paramount features of all parts of these apparatus. Cumbersome and delicate laboratory models of a few

months ago have become robust, mass-produced units. Design urges less space and more performance. This imposes greater electrical strain, higher operating temperatures, and the need for greater dimensional accuracy and stability upon the insulation. Communications use higher and still higher frequencies, with the insistence upon lower and lower power losses. These requirements are met by several plastic groups. The phenolics take major place.

Applications of Laminated Sheet

Impregnated laminated sheet of paper base or similar material of higher electrical grades having very low water absorption, improved power factor, better hardness and resistance to plastic flow under pressure fulfil the needs for insulating separators, panels of various descriptions and miscellaneous components. While these are much improved in quality, nevertheless fabrication needs of blanking and drilling or piercing have not been foregone. Fabric laminated material to withstand greater bursting stresses are also available in electrical qualities not far short of the paper reinforced products. Asbestos laminated for fire resistance and heat stability has been given its quota of attention, and the thinner sheets for blanking and piercing can be relied upon to give accurate components without disproportionate tool wear, cracked parts or frayed edges. Paper laminated tubes of rolled and moulded quality are obtainable for use in conjunction with the sheet materials in closely similar electrical grade. Ordinary moulding powders have been improved and the technique of using them correspondingly controlled to give low moisture content mouldings of improved electrical characteristics, while by the incorporation of special mineral fillers, power losses at high frequency have been brought within a tolerable limit. Again, a wide study of textile filling has resulted in a range of impact resisting moulding materials more suited to the mechanical severity of many services requirements. These have often replaced wood which could not be relied upon electrically and needed fabric covering for impact resistance, with the advantage of more rapid production to greater accuracy in dimensions.

Polystyrenes, Etc.

The polystyrene group provides powders for rapid injection moulding processes whereby very intricate, thin sectioned, close dimensioned articles can be correctly manufactured. Sheet, rod and tube forms of this material permit of machined and shaped components being made. This group of materials has excellent power factors at radio frequencies and provides many items for services intercommunications.

The ebonites or hard rubbers meet the arduous situations. Special mineral loaded ebonites of the "composite insulating material" group are readily procurable in the form of sheet or rod, or as mouldings; they exhibit good loss factors, good behaviour under corona conditions and are a prominent material in radio equipments. Ordinary ebonites are available in the standard black electrical grades but produced under controlled conditions to permit of blanking operations being performed in the thinner sizes without heating. With special fillers, improved power factors of these have been obtained and regularly reproduced.

Value of Amino Resins

The amino or urea products are still pre-eminent on account of resistance to tracking. Available in distinctive but permanent colours, they are useful for colour control schemes, that is, switch handles. Also, in translucent thin sheet forms, they are indispensable for instrument scales. Some of the latter are very complex and must resist dimensional movement.

For large panel work, coloured phenolics, phenolics veneered with amino sheet, or mineral loaded amino material, have positive use apart from the normal natural phenolics. Much remote control work involves system diagrams on these panels. They can either be stencil sprayed with cellulose enamel, or printed by a special process on the top sheet of paper incorporated in the board.

Insulating sleeving for wires and cabling has always been a special problem. For some years polyvinyl chloride sleevings have been available. These are excellent for electric strength, flexibility and inertness, and good for resistance to ageing or dimensional change. Multiplicity of colours for coding reasons, and of bore diameters and wall thicknesses are required and obtainable. Added to the list are now the polythene type, while, furthermore, reinforced varieties such as polythene core with impregnated outer fabric covering, or lapped acetate core similarly covered have now been quickly developed to answer a need.

Small core insulation finds a ready supply of electrical quality cellulose acetate foil in a quality much superior to ordinary wrapping foils, with particular reference to resistance to ageing and embrittlement. These foils in thicknesses from 0.001 in. to 0.010 in. are excellent for electric strength and retention of this value under damp or warm conditions.

2. Mouldings for Reproducibility

Machine capacity has its limitations and complexities of modern design are apt to create much turning and shaping. The plastic moulder offers the answer for relief of congestion in these directions In the phenolics there is a choice of a range of moulding powders to suit the complexity of component without reflection in the properties of the product. Then again, there are the ranges of impact materials and of mineral filled from which one can be selected with a final function in mind, yet to give greatest alleviation to tool wear and speed of production.

The moulder collaborating with the engineer at the tender stage, before tools are made, can ensure that his dies are produced to maintain close dimensions at critical points, flat areas where required and freedom from flash where least desirable, and accommodate his own needs elsewhere.

3. Sheet for Panellings and Other Forms of Mechanical Needs

Phenolic laminated sheet materials have in a large number of instances "stepped straight into the breach" to substitute light alloys in order to free the latter for essential air-borne equipments. Often strength and stiffness have been adequate without any change in design or thickening up; thus this has applied to gauges of 0.093 in. and over. Thinner sheets have sometimes to be changed to something heavier in order to give the requisite rigidity and impact. Metal-sprayed coatings or adhesive-secured metal veneers can be provided if electrical conduction is required; the coloured amino veneers can be incorporated if a "finishing" scheme is necessary. All these statements apply particularly to radio transmitting and receiving equipments and to electrical control apparatus. But phenolic sheet and strip material can, owing to its stability and inertness, be used to replace flat metal blanks or piercings, especially those of aluminium. This can be seen from

changes in telephone apparatus as well as in other light electrical equipment. Thus the aluminium spacing components in switch banks can quite successfully be replaced by paper laminated; stainless steel head bands are effectively made from fabric laminated and shaped by a heat-setting process.

Mention must be made of phenolic resin laminated wood, relatively a newcomer to the field. It possesses many of the attributes of the other phenolic laminated materials, with additionally special claims for constructional work on account of strength and manipulability.

The substitution of light alloy castings by phenolics has extensively occurred and will be exploited further yet. True this cannot apply in every case, particularly those in which very close dimensional limits are involved, and more especially when on the same casting a number of dimensions are critical not only in themselves but also in relation to one another.

Rods, tubes and sections and metal reinforced rods assist materially in replacing metals, stainless steel and aluminium alloys, primarily in small structures. The phenolics are pre-eminent in these directions, with fabric laminated of particular utility for higher crushing or bursting stresses as well as for wear resistance.

4. Glass Substitutes

The methyl methacrylates are true glass substitutes by virtue of their excellent clarity. Moulded forms are especially useful for small instrument windows, but sheets or panels are used for the same purpose. Made from this glass-clear resin, components can be accurate and so eliminate the main difficulty with glass itself. The critical lenses of optical systems can likewise be exactly reproduced in this material.

The thicker grades of cellulose acetate have always claimed attention for window applications, but for thinner gauges wire reinforced products are more favoured for mitigating expansion and contraction troubles.

Polyvinyl chloride sheet in transparent form is apparently not yet available in this country to carry on the successful exploitation of the Continental "astralon." On the other hand, one must not overlook the translucent amino laminated plastics in thicknesses up to at least ⅛ in. These are very successful for signs, labels, scales and so forth where reflection from within is required.

5. Specifically Severe Conditions

Mention has already been made of textile filled mouldings for shock resistance. Phenolic laminated has been employed for rolls in heavy rolling mills. Fabric laminated is much sought after in gear work for silent running, smooth operating and negligible wear. For some rubbing components, a graphite containing moulding powder is used to reduce friction, wear and loss of adjustment.

The suddenly boosted load on engineering means much new equipment and new or more rapid processes. This particularly applies to "metal finishing." For example, "pickling" is an operation with which all producers of steel in rod, sheet, tube, wire or section are intimately concerned. Likewise those operating hot-dip tinning and electro-plating plants, heat treatment and many finishing processes. Space frequently means that processes must be rendered more rapid instead of expansion. Consequently pickles are used hotter, and as a result something more resistant becomes necessary. Proprietary chemical resisting phenolics having heavy mineral loading such as siliceous matter are available. Rapid service in their fabrication into tanks, baskets, trays, racks and other shapes is given. Good working life is obtained under strenuous conditions.

Modern electro-plating vats are practically all hard rubber lined. The advantages are no corrosion, no electrical leakage, cleanliness, and no contamination of solutions. But to meet present fluctuating conditions they enable a given vat to be rapidly changed over from one type of solution to another, a practice not always possible with steel or lead-lined vats. From the phenolics, moulded or laminated, and the soft or hard rubbers, most chemical conditions can be catered for; exceptions are concentrated strongly oxidizing solutions.

Plastics for Domestic Service

Plastics have served domesticity for years with utensils such as cups and saucers, plates and dishes, etc. This service ceases to be one of mere taste or artistry, but becomes a real utility. Present conditions often demand something less breakable, free from the "glass" danger and more portable. But in the food sphere, plastics serve in packaging with materials such as Pliofilm, moisture-proof "Cellophane" and cellulose acetates, these substituting aluminium foils of all kinds as well as various parchmentized papers.

With respect to fire resistance, all the phenolics are in the ordinary sense resistant. Asbestos-filled varieties can be used in the more extreme cases. The loaded ebonites are more heat and fire resistant than ordinary ebonites, and some are claimed to be satisfactory for operating as high as 100 degrees C. without distortion. The chlorine containing rubbers are more fireproof than ordinary rubbers.

Rubber is a very important plastic, and many applications demand one that is heat and oil resistant, with retention of this property over long periods. The synthetics of the neoprene variety answer these requirements admirably; experience over long periods shows that they retain their physical and mechanical characteristics at a remarkably constant level.

Summarizing, the plastics industry having created a nucleus of technicians, skilled operatives, techniques and plants is not only able to fulfil all its own commitments under the very trying conditions, but to substitute important materials that have other prior claims. Moreover, it has an answer for most of the propositions put to it, an answer which is refreshingly positive in nature.

EMPIRE MINERAL RESOURCES

A valuable and interesting paper by S. J. Johnstone, F.I.C., on "The Empire Mineral Resources and the Relation to the War Effort" has just been reprinted by the Institute of Chemistry. The author describes the great wealth possessed by the Empire in most metals, minerals for the chemical industry and non-metallic minerals such as asbestos, asphalt, corundum, talc, mica, graphite, many of which are of great importance to the plastics industry. The sources, production figures and applications of these minerals are fully described. There are also valuable graphs showing the relationship between Empire and world outputs.

OBITUARY

We regret to announce that Mr. William Grantley Hyde, senior director of May and Baker, Ltd., died on Wednesday, February 26, 1941, at his home, Milestones, Forest Road, Tunbridge Wells, Kent, in his 73rd year.

PRODUCTION

Practical Information dealing with Raw Materials, Moulding and Forming of all types of Plastics—Thermo-Hardening and Thermo-Plastic—Works-Organization, New Plant and Control Apparatus

NOTES AND COMMENTS

THE OLDEST PLASTIC.—While we talk glibly of the fact that bitumen, in which we include asphalt, is the oldest plastic, apparently having been used by a very old boatbuilder, it remains a fact that industrially bitumen became an important material only when the chemical industry demanded it as an anti-corrosion compound, when the electrical industry found it useful as a dielectric, when road building assumed importance because of the growth of the motor industry, and when this last found it useful as a moulding material for holding acid accumulators.

Nevertheless, there is still much to learn about bitumen and there is still room for improvement. Certainly the road constructors are not too pleased with it, for it has poor adhesion to the mineral aggregate which it is presumed to bind. Recently Dr. C. Mack, of the Imperial Oil Co., Ontario, discussed this adhesion in a paper at the Chemical Society. There is no doubt that this property can be improved by the addition of certain agents. Among these copper sulphate and ferric chloride were mentioned as being useful; presumably in the latter case some oxidization or decomposition to more viscous and more adhesive compounds takes place.

It is interesting to note a recent patent by the Standard Oil Co. which avoids direct admixture with bitumen, but induces adhesion to a road surface by covering the latter with a film of lead naphthanate, a material of great "stickiness," before finishing with bitumen.

There is little doubt that the adhesion of bitumen to mineral aggregate can be achieved very easily, but the chief deterrent of most methods lies in the fact that economically bitumen can stand little or no increase in price.

These notes carry sufficient interest for plastics generally, since their modification in one way or another grows apace. It is obvious that these problems are akin to plasticizing and that the road constructors can learn something from the plastics industry. The reverse is also obviously true.

NEW ART PLASTICS COMPANY.—There has just been formed a new concern, Ambrican General Trust, Ltd., which promises to fulfil the dreams of a large section of the British plastics industry—the introduction of truly artistic forms in plastic goods. The chief light of this concern is a Mr. Landsberger, who was famed in Germany for his beautiful plastics-metal combinations for a variety of objets d'art, jewellery, cases, door handles, and so on. Such production to-day in Britain seems strange, but Mr. Landsberger's present object is to create a valuable export trade in order that a modicum of foreign exchange will reach this country. Among many of the remarkable things he has shown us is what, in bald print, may seem insignificant or unimportant—the wooden models for a series of coat-hangers. They are not, however, merely coat-hangers—they are gems of the plastic art. It will be at once argued that nobody wants artistic coat-hangers. It is only necessary to see these, however, to change one's mind. We have never yet seen their like. This is a tantalizing description and one day we hope to have the pleasure of photographing them, and if these examples become a moulded and commercial reality Mr. Landsberger will deserve an honoured place in the plastics industry of this country.

"MODERN PLASTICS CATALOG."—The Breskin Publishing Corporation, of 122 East 42nd Street, New York, publishers of *Modern Plastics*, has sent us the new 1941 edition of this catalogue. It is difficult to describe this work without employing extravagant phrases. Certainly the publishers are modest, for it is a considerable understatement to call this a catalogue. It is a truly magnificent compilation, beautifully printed and covered, and is the most complete technical and commercial encyclopædia of plastics we have yet seen. Lavishly illustrated in the American style, it contains a great number of photographs of a vast range of applications in almost every industry, heavy and light. A large proportion of this 500-page book contains a series of articles by well-known experts on the production of the raw materials of the industry and on their moulding, fabricating, shaping and machining. Very complete data on the engineering, chemical and electrical properties of all the commercially produced plastics make this volume of great importance to plastic worker and user alike. It is priced at $3.50.

PLASTICS CONTROL.—In our last issue we published the official information that Mr. L. P. B. Merriam had been appointed to the post of Controller of Plastics. We have now much pleasure in reporting that Mr. C. H. Glassey, who has helped Mr. Merriam since the Control was first formed, has now been appointed Deputy Controller.

Temperature Measurement and Control in the Plastics Industries

Temperature control in one way or another is practised by all workers in the moulding industry, and its importance is realized, but how close such control is carried out varies considerably. The following article deals with heat control instruments of the most up-to-date type and while there are many such on the market, deals with those developed by the Cambridge Instrument Co., Ltd.

THE present exceptional conditions and the ever-increasing demand for efficiency and economy render essential the use of the most effective production methods by both chemist and engineer. In this connection a major necessity is that processes involving specific temperatures should be subjected to accurate measurement and in many instances maintained.

The use of instruments in the plastic industry, and in such associated fields as varnish manufacture, rubber processing, etc., has seemed rather to show a tendency to lag in the past and an apparent lack of appreciation of scientific control methods has been remarked. Compared, for instance, with the metallurgical industries, the effective use of instruments has been comparatively neglected, although the requirements of temperature measurement in many processes is equally great. It is not suggested that this was an instance of an industry unwilling to supersede empirical practices by scientific control and modern methods, but rather the lag has been due to unknown factors which are met with in industries which utilize so many raw materials, and whose processes are far from being completely understood in the chemical and physical sense. Experience in research and production, both in this country and abroad, has helped to elucidate many problems and to devise production methods, which in many cases render imperative the need for a wider use of temperature measuring apparatus. In this manner, early "heat and hope" methods have been superseded by modern practices providing reliable products of consistent and uniform quality. Many processes still present individual difficulties. In varnish manufacture, for instance, means of rapid cooling are often more important than rate of heating, especially in exothermic reactions, as in the heat polymerization of drying oils. Again, convection factors may be altered by changes in viscosity during processing, permitting local overheating. In the former case, an accurate recording thermometer would prove invaluable, whilst in the latter instance, such recordings might prove fictitious and misleading unless the condition of viscosity and subsequent convection taking place were allowed for; in this connection the situation of the sensitive measuring bulb would be of importance.

It is still found in many instances that simplicity and adaptability of an instrument is of greater importance than extreme precision and it is proposed mainly to review instruments with this in mind.

Temperature, being an intensive magnitude and not additive, can be measured only by indirect methods, by transferring the internal atomic energy of the body or material in question to an instrument designed to respond to the energy so transferred.

Lord Kelvin was responsible for the establishment of a standard temperature scale, based upon the law of the expansion of gases with temperature: this scale is termed the thermo-dynamic or absolute scale. The standard thermometer consists of a gas (hydrogen) enclosed in an envelope in which the change of pressure with temperature is accurately measured.

Although the gas thermometer is of fundamental importance in determining standard temperatures, it is too elaborate and difficult to be used in the majority of laboratories or workshops. Other means of measuring temperature have therefore to be devised. Any property of a substance which varies with temperature can theoretically form the basis of a temperature-measuring instrument. Many properties have been used, but for our present purpose it is proposed to deal only with methods given in the table* below.

Type	Description	Range and Remarks	
Liquid expansion	Toluol or pentane in glass. Mercury in glass	−200°C. to +30°C. −30°C. to +500°C.	Indicating
Liquid expansion	Mercury in steel	−40°C. to 600°C. Readings can be transmitted up to distances of 120 feet.	Indicating and Recording
Vapour Pressure	Ether or other organic liquid	−50°C. to 400°C. Readings can be transmitted up to distances of 120 feet.	Indicating and Recording
Vapour Pressure	Mercury in steel	350°C. to 700°C. Readings can be transmitted up to distances of 120 feet.	Indicating and Recording

Mercury in Glass Thermometers

The indication of a liquid thermometer depends on the expansion of the liquid relative to the expansion of the envelope containing it; the greater the difference between the two expansions the more sensitive the thermometer. These thermometers have been compared with the gas thermometer up to temperatures of 300 degrees C. with great accuracy and in this way a series of thermometers have been built up which form secondary standards, against which (within their range) the thermometers in general use are standardized. These secondary standards are held in the national physical laboratories of the world. The accuracy now obtainable with a correctly standardized mercury-in-glass thermometer is very high. Within a range of 0 degree to 200 degrees C. a temperature can be determined to within 0·001 degree C. An accuracy of this order is rarely required in industry, but it may be assumed that within the range of the industrial type an accuracy of 0.1 per cent. of the range can be obtained.

Although the earliest form of thermometer, these are still in general use. They may be arranged to give a very open scale, and within their range are capable of being read to a high degree of accuracy. For precise work, the thermometers should be standardized and corrections for variation in the bore of the glass

* S. L. Barron. "Accurate Measurement of Temperature." Harrogate Varnish Symposium. May, 1939.

capillary, for depth of immersion and for hydrostatic pressure in the bulb, should be applied. Such standardization is carried out by the National Physical Laboratory. In thermometers for industrial purposes, such corrections, within the accuracy guaranteed, are applied usually by the makers during calibration. Thermometers in daily use should be checked at intervals against a standard thermometer. Glass thermometers are fragile and various forms of protective guards have been devised (see Fig. 1); they cannot easily be read in a dull light and although angle patterns are made, it is not always possible to mount them in accessible situations.

Mercury-in-steel and Vapour-pressure Thermometers

The usefulness of mercury or liquid-in-glass thermometers is limited by their fragility and also by the difficulty of reading the thermometer in dark or inaccessible positions. These drawbacks have been overcome by the introduction of the mercury-in-steel and of the vapour-pressure thermometers. Both these instruments function as pressure gauges. The bulb of the thermometer is connected by means of a fine capillary tube to a Bourdon pressure gauge. An increase in the temperature of the bulb raises the pressure throughout the system (see Fig. 2). Both types are made up as either indicators or thermographs and have the outstanding advantage of simplicity. Fig. 4 shows two thermographs of the type illustrated diagrammatically in Fig. 2, installed on presses in the moulding department of E. K. Cole, Ltd., Southend. The presses are employed in the manufacture of wireless cabinets. The bulb of the thermometer is placed in the hot zone and the indicator or recorder placed in the most convenient position for the purpose. Assuming that, as a general rule, the distance between the bulb and the instrument does not exceed 100 ft., an accuracy of 1 per cent. may be relied upon. The effect of temperature on the capillary, assuming that it does not exceed 50 degrees C., may be neglected. These thermometers are rapidly replacing glass thermometers for industrial use, owing to their greater robustness and the fact that the indicating or recording dial may be situated at a distance from the heat-receiving bulb. This enables the dial to be placed at eye-level in a convenient position irrespective of the inaccessibility of the bulb (see Fig. 3). It also enables a number of instruments to be grouped together for convenient observation when various processes are being carried out in one department. Bulbs and capillary tubing are made of various materials, and can be suitably treated or protected to withstand the different forms of corrosion met with in industrial use. If a process involves the use of corrosive materials, or if corrosive fumes are present, it is always desirable to consult the manufacturers, who will advise as to the best form of protective covering.

In vapour-pressure thermometers, owing to the effect of hydrostatic head, it is necessary for the maker to know the relative heights of the bulb and the dial, so that the instrument can be calibrated for such conditions. This is less important in thermometers with high ranges and does not affect instruments with rigid tubes and short lengths of capillary.

Fig. 1.—Standard glass thermometer protected with a guard.

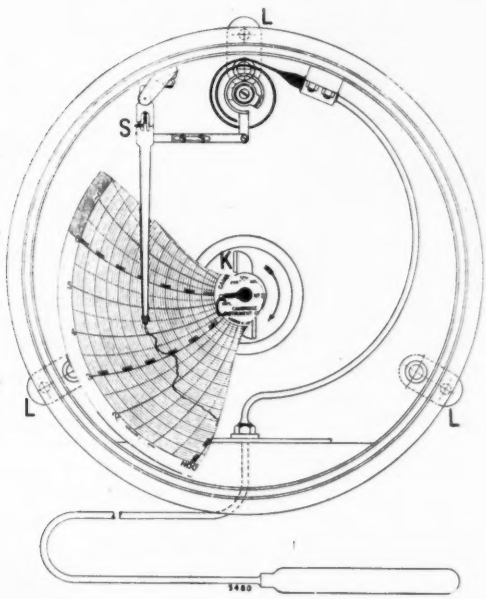


Fig. 2.—Diagram of thermograph.

Fig. 3.—Mercury-in-steel indicator.

Automatic Temperature Control

In certain processes it is often desirable that the working temperatures should be controlled to a constant value, and many forms of temperature regulators of the mechanical type are available for this purpose. In the moulds for "phenolic" powder presses, satisfactory results can be secured only if the temperatures in the mould are maintained within definite limits, the permissible variation in temperature being dependent upon the nature of the material being moulded.

A simple form of regulator is the bi-metallic type which depends upon the different coefficient of expansion of two dissimilar metals. These metals are rigidly fixed to one another and carry at one end a form of contact. When the metals are heated, the fact that one expands more than the other will cause the

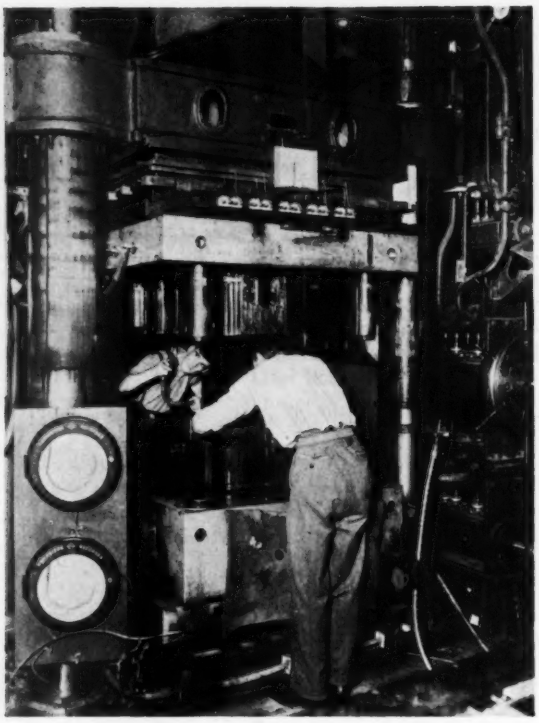


Fig. 4.—Thermograph-type installed on presses at the works of E. K. Cole, Ltd.

bi-metallic strip to bend and thereby open or close the contact. This contact may operate auxiliary contactors. This type of regulator obviously has a restricted application due to a limited temperature range.

Control with Great Accuracy

Where control apparatus of greater accuracy, range and adaptability is required, indicating or recording, the instruments described at an earlier stage and illustrated in Figs. 3 and 4 may be obtained fitted with adjustable electrical contacts which can be arranged to operate whenever the pointer or pen reaches a predetermined position, corresponding to the desired control temperature. The operation of these contacts is usually arranged to actuate electric contactors which in turn will open or close electrical heating circuits, or bring into action other controlling apparatus. Providing circuits are non-inductive the contacts fitted to the mechanical type of regulator will usually carry a current of about 0.1 ampere up to 250 volts, which is sufficient directly to operate auxiliary contactors for loadings up to 30 amperes at line volts. Some manufacturers arrange these contacts to operate mercury switches self-contained in the regulator, which enable circuits up to 15 or 20 amps. to be opened or closed, thus eliminating the necessity of external and additional auxiliary apparatus.

Thermograph-control Type

A typical thermograph used as a controller is illustrated in Fig. 5, the case being cut away to show the scale mounted within the case, at which the desired control temperature may be set. It is simple and of robust design, the usual duration of the chart being 24 hours or 7 days. It is possible to obtain instruments with "set up" ranges so that the chart corresponds to the working temperature range, whilst double regulators, fitted with recording systems for controlling and recording temperature at two different points, are also available. Most manufacturers employ reliable clock mechanisms to drive the charts in these instruments, but for special applications where A.C. mains are available synchronous motors can be obtained. The cases are arranged for either wall or flush mounting and to facilitate changing of charts devices are often provided which automatically hold the pen clear of the chart as soon as the door is opened.

Automatic Regulation of Temperature

A convenient and simple form of automatic regulator, known as the Thermometer Regulator, has recently been successfully applied to the plastics industry. Fig. 6 shows two of these instruments controlling the temperature of a small moulding press. Indication of temperature is given on a clearly marked 4-in. dial, and the accuracy of control is such that an instrument having a range of 100 degrees to 400 degrees centigrade will operate to within plus or minus 2 degrees. The instrument is compact, self-contained and inexpensive, whilst a special feature is a self-contained switch with a maximum current capacity of 12 amperes at line voltage, which normally renders unnecessary the employment of an auxiliary contactor circuit. The adjustable contact on the thermometer dial is spring mounted on a movable red index, which is set by hand to the temperature at which control is desired. When the temperature is low the thermometer contacts are closed, energizing the switch and closing the main contacts; when the indicating pointer reaches the red index the thermometer contacts open circuit and thus open the main contacts. There is a small time lag of about 1½ secs. between the time that the thermometer contacts open circuit and the operation of the main contacts caused by the switch mechanism; this time lag in the opening of the main contacts protects the latter against vibration troubles.

The main contacts of the switch are made normally

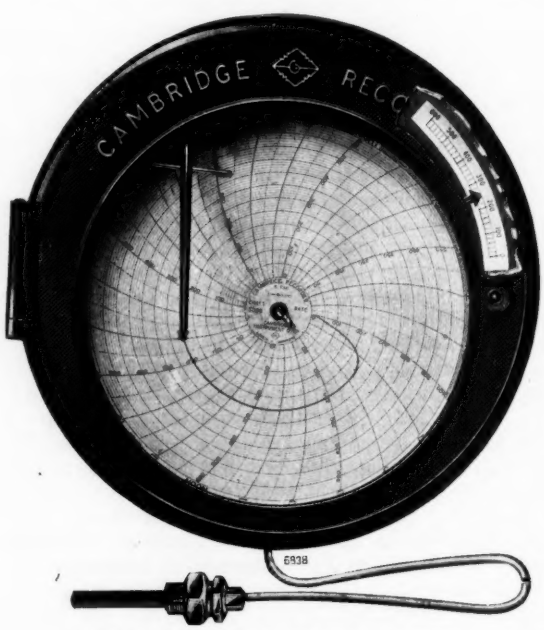


Fig. 5.—Thermograph used as a controller.

open and require an electric current to close them; this arrangement has the advantage that in the event of any fault developing in the wires connecting the instrument the main contacts will immediately open circuit and prevent damage to the process through overheating.

Conclusion

It is important that careful consideration should be given to the installation and maintenance of temperature instruments. It has often been found that reports of unsatisfactory operation in instruments can be traced, not to faulty design, but to careless use, neglect and oft-times damage due to lack of imagination in installing the apparatus in the first instance.

The life and successful use of an instrument depends to a large degree upon the care taken in mounting it in a suitable position. Where possible, they should be installed in accessible well-lighted positions on the eye line. They should be conveniently situated for the workmen to make observations, but should not be subjected to high or rapidly changing temperatures. If exposed conditions be unavoidable, a separate case or housing is desirable. The capillary tubing of the instruments should be carefully bent into position and firmly fixed to a wall or supporting structure; it should not be bent too sharply or the very fine bore may be partially blocked. If, when installed, the capillary is too long, it may be coiled and fixed near the instrument case. A few hard and fast rules only can be laid down and it is obviously not possible, in the limited space of this article, to deal adequately with the subjects treated. Further guidance in the choice of upkeep of temperature regulators is always available upon application to any of the reputable makers.

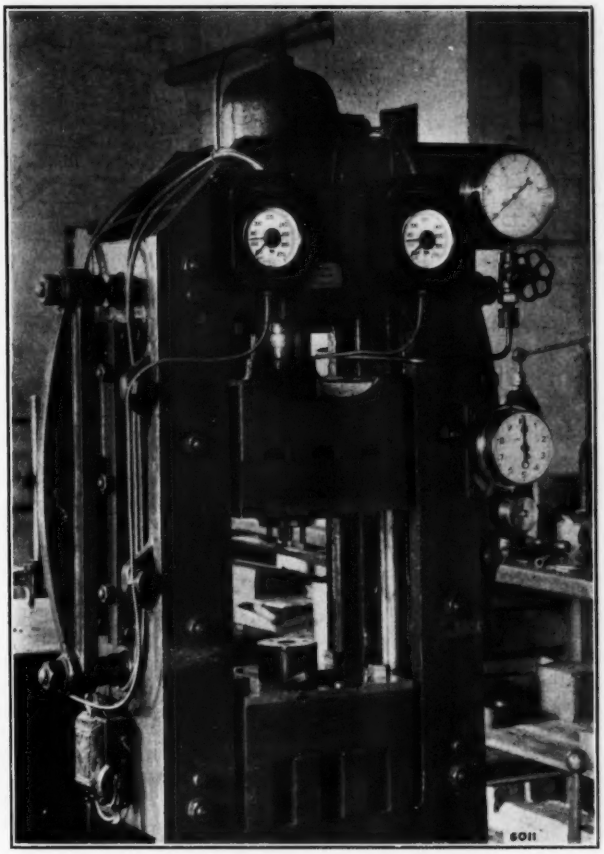


Fig. 6.—Thermometer regulators fitted on a plastics press.

No mention has been made in these notes of other forms of temperature measurement, such as thermo-electric or resistance thermometers, as these do not so readily find application in the plastics industry. One exception, however, is a form of surface thermometer for measuring mould temperatures, that consists of a flat strip of thermo-electric metal, which when placed in contact with the mould surface causes an electric indicator rapidly to register the temperature. Full details of this special application is given in the Cambridge Instrument Co.'s publication on Surface Temperature Measurement.

PLASTICS AND POWDER METALLURGY

(Continued from p. 51)

that an oxide film can have on the properties of the particle. In some cases the actual shape of the particle may be important, especially where covering powder enters into the scheme of things, for then flake-like or laminated particles are called for, and their mode of production is entirely different from those used to produce spherical on dendritic particles.

It will be appreciated that on both the plastic and the metal powder side there are many points that require investigation, and that the greatest value and information is likely to accrue from the closest co-operation between the worker in plastics and the powder metallurgist. It can, in fact, be said without fear of contradiction that real progress in the application and use of metal powders in plastics can come only through such co-operation.

Each Application Has Its Own Problems

It must also be emphasized that in no small degree each problem as it arises will require specific consideration. This is only what happens in most technical industries. In other fields the necessity for this special study has been learned by bitter experience. The plastics industry is in a more favoured position, for it has the accumulated experience of other industries at its disposal, and, in addition, a product which obviously offers remarkable possibilities when it can successfully utilize metallic powders to enhance its appearance, improve its qualities, or confer upon them some new and desirable property. Wide as is the field covered by plastics to-day, the combination of plastics with metal powders, carried out in the right way, can immeasurably widen the scope and the usefulness of plastics to the enduring benefit of both the public who uses and the industry which produces them.

LOW SPECIFIC GRAVITY SYNTHETICS

Our remarks on polythene being the lightest resin known has brought us the information that Isolene, a trade name for a polyisobutylene, is of about the same specific gravity, namely, 0.93. This, too, is a rubber-like compound and is employed for the production of electric cables, resembling polythene very closely in electrical and also chemical properties.

RESEARCH IN THE INDUSTRY

The Resistance of Plastics to Water and Chemical Reagents

MANUFACTURERS of electrical appliances and equipment have long been among the best customers of the plastics industry. At the same time, they have been most stringent in their requirements.

A characteristic of particular importance to the electrical industry is the behaviour of plastics in use. As insulating materials plastics are uniformly excellent. They all have an electrical resistance which is initially very high. This can be measured and the details of insulator design evaluated accordingly, but allowance must be made for the deterioration in electrical properties which is known to occur under conditions of exposure to water or chemical reagents. The amount of such deterioration is impossible to forecast with any degree of accuracy and no amount of research has been able to put this problem on a quantitative basis and even qualitative evidence is much confused.

Exposure also results in dimensional changes which are frequently troublesome and which may, under certain conditions, give rise to cracking and cause the insulator to split.

In this connection some lengthy papers, recently published in Russia, are of particular interest.

Resistance to Water

The first of these investigations[1] was concerned with the resistance of phenolics to immersion in water, the duration of these tests being 36 months. It was found that all the specimens reached their limiting moisture saturation after immersion for 15 to 24 months, after which they ceased to suffer any further dimensional changes. The increase in weight amounted to from 5 to 8.5 per cent., the elongation being 1 to 2 per cent. The method of moulding has a considerable bearing on the water resistance of the product, the semi-dry and dry methods of production being definitely unsuitable. Much better resistance was obtained using the lacquer and emulsion methods, whilst excellent results were obtained on specimens formed by the rolling method. This last method was satisfactory for both novolacs and resols, for which the limiting saturation after 36 months' exposure averaged 6.5 per cent. and elongation 1.4 per cent.

In another paper[2] two of these investigators have extended this research to cover exposure to water vapour. The conclusions reached were very much the same as for immersion in water, the major difference being that specimens take longer to saturate in moist air than they do in water. Thus, it was found that the increase in weight in water vapour amounted to only 0.6 to 0.9 of the increase in weight when immersed in water for the same length of time. A study of the prolonged (up to two years) action of air saturated with water vapour on specimens prepared from different moulding materials showed that to each degree of humidity of the air there corresponds a limiting saturation on drying. Over the range 0 to 80 per cent. relative humidity of the air the magnitude of the limiting saturation, Q, is given by the equation $Q=a(W-b)$ where W is the relative humidity of the air and a and b are constants depending on the resin. Thus, for a particular resin, $Q=0.0571(W-38.6)$.

For a certain relative humidity, the value of which varies for different moulding powders, there is established an equilibrium when practically no change in weight or dimensions of the specimen occurs on exposure. In the example quoted above, the relative humidity at which this very desirable state of affairs exists, is 38.6. At humidities above this value moisture is absorbed, causing a loss in electrical resistance and an increase in dimensions. Below this figure the plastic tends to dry out, resulting in shrinkage and possible cracking. Moreover, there exists a relation, differing for different moulding powders, between this equilibrium point and the moisture content of the powder before moulding. The higher the original moisture content of the powder, the higher is the relative humidity of the air at which equilibrium is established.

The meaning of all this research is, that by suitably choosing the initial moisture content of the moulding powder it is possible to produce moulded products for use at a particular humidity, which will not suffer any change in moisture content or in dimensions during service. An alternative method of producing such a stable product is to keep the cast resin for nine months or so at the humidity at which it is to be used before being put into service, since it was established that after exposure to air of the same humidity for periods of this order the dielectric properties of mouldings obtained from powders with differential initial moisture contents tend to become equal.

Another factor which must be taken into account is the variation of surface resistance with change in moisture content of the air. This decreases with increasing humidity of the air and it was found that the limiting surface resistance amounted to 10^9 ohms for a specimen situated in air saturated with water vapour and between 10^{14} and 10^{12} ohms for a specimen in dry air (0 per cent. relative humidity). These values agree well with the results obtained by other investigators, notably Curtis, of the American Bureau of Standards. (See Table I.)

Influence of Composition

Sokolov and Zarubina[3] have also investigated the influence of chemical composition on the resistance of phenol-formaldehyde and cresol-formaldehyde resins to various chemical reagents. Both novolacs and resites were studied, prepared from 5 molecular proportions of phenol or cresol to 4, 6, 8, 10 or 12 molecular proportions of formaldehyde. The tests were carried out at room temperature in 50 per cent. sulphuric acid, concentrated hydrochloric acid (specific gravity 1.19), 10 per cent. sodium carbonate solution, 5 per cent. solution of sodium hydroxide, water and ethyl alcohol. Whilst most of these tests lasted for 30 or 120 days, others varied in duration from 24 hours to one year.

The main conclusion from the mass of experimental evidence obtained is that no resin exists which is equally resistant to all the chemical reagents studied. A high resistance to one is not associated with an equally high resistance to another reagent.

Generally speaking, resites are more resistant to acids than novolacs and the phenolic resites more so than the plastics prepared from cresol and formaldehyde. All specimens were sensitive to water and showed an increase in weight of 0.5 to 3 per cent. after one year. This seems somewhat low in comparison with the figures, given earlier in this article, obtained by these research workers in their investigations on the water resistance of phenolic plastics. Cresolic resites were somewhat better than phenolic materials in resistance to both water and sodium carbonate solution.

A comparison of the behaviour of the products obtained by varying the ratio of constituent phenol and formaldehyde showed that this ratio has a greater effect on chemical resistance than has hitherto thought to be the case. A deficiency of formaldehyde produces novolacs and resites which are rapidly destroyed by the action of alcohol. Specimens prepared with excess formaldehyde possess a much higher resistance to alkalis and alcohol. Novolacs with 20 per cent. urotropine are particularly effective. It is well known that the use of excess formaldehyde tends to produce a

harder resin and probably this has something to do with the improved resistance of materials so prepared.

Resistance to alcohol seems to be the main difficulty at the moment. The cresolic resites in particular are extremely sensitive, showing a rapid increase in weight and being soon destroyed. Increasing the proportion of formaldehyde employed does not materially improve the resistance of cresolic resites to alcohol.

The proportion of formaldehyde also affects the course of attack, since it was found that decreasing the amount of formaldehyde tended generally to result in an increase in the weight on exposure. Using a larger proportion of formaldehyde tended to reverse this course of action.

Speaking in general terms, the smallest changes in weight and in dimensions were exhibited by phenolic resins prepared from approximately equal molecular proportions of phenol and formaldehyde.

It is thus apparent that resins with optimum properties can be produced only under conditions of accurate scientific control. It is well known, however, that the difficulty of controlling the composition of resins is a very real one. During the condensation of the constituents and also during the subsequent polymerization, a good deal of formaldehyde and also some phenol escapes to the atmosphere. The same thing happens during the drying of the finished resin, indicating, as has been proved in other ways, that phenol-formaldehyde plastics may contain quite considerable amounts of unreacted phenol and formaldehyde. Whilst little definite evidence is available regarding the nature of the effect of these unreacted constituents on the properties of the plastic, it is known that their influence is by no means inconsiderable. Phenol, for instance, frequently has a plasticizing action and its presence in plastics intended for use in proximity to water or chemical reagents is most likely to be extremely deleterious since a softer resin should be more easily attacked and should more readily absorb the corroding agent than one possessing a hard, non-absorbent structure. This links up with the observation, described above, that both novolacs and resites possess a greater resistance to water when made using excess formaldehyde.

Reduction of Phenol

In commercial practice advantage is taken of the escape of phenol during the drying process in an open pot to reduce the amount of uncombined phenol to the desired figure. The progress of this operation is followed by means of quantitative analysis, which is a laborious operation requiring skilled labour for its accurate evaluation. Nevertheless, it is essential that the exact quantity of uncombined reagents be known and an alternative procedure of simple but reliable character would be welcomed as a great aid to the production of plastics of scientifically controlled characteristics.

Table I.—The Resistivity of Some Dielectric Materials*

Material	Temp. °C.	Volume Resistivity		Surface Resistivity, Ohm-cm.	
		P Ohm-cm.	P^{20}/P^{90}	Humidity 50%	Humidity 90%
Amberite	22	5×10^{16}		2×10^{13}	3×10^{12}
Bakelite†	22				
No. 1		2×10^{11}		3×10^{11}	2×10^{8}
140		2×10^{7}	2.4	3×10^{9}	2×10^{5}
150		4×10^{12}	3.6	3×10^{12}	4×10^{9}
190		1×10^{11}	3.6	1×10^{11}	5×10^{8}
L558		2×10^{16}	2.6	8×10^{15}	8×10^{14}
G5,074		4×10^{10}		3×10^{11}	5×10^{5}
5,199RGRB		5×10^{12}		6×10^{12}	1×10^{10}
5,200		4×10^{11}	5.3	1×10^{12}	5×10^{9}
Beeswax	20	$8\text{-}20\times10^{11}$	160	6×10^{14}	5×10^{14}
Duranoid	22	3×10^{13}		6×10^{12}	3×10^{9}
Rubber	22	10^{15} to 10^{18}		3×10^{15}	2×10^{9}
Shellac	22	10^{16}	1.5	5×10^{13}	6×10^{9}
Slate	22	10^{9}		9×10^{6}	1×10^{6}

* Handbook of Chemistry and Physics.
† For details of these Bakelite samples, see Table II.

Table II.—Composition of Bakelite Samples

Number	% Pure Bakelite	Filler	Phenolic Body	Condensing Agent
1	50	Paper	Cresols	Ammonia
140	50	Vegetable	Phenol	Caustic soda
150	50	Fibre	Phenol	Ammonia
190	50	Fibre	Cresols	Ammonia
5,199	50	Fibre	Phenol	Ammonia
5,200	50	Fibre and Clay	Phenol	Ammonia
5,074	35	Talc	Phenol	Caustic soda
588	100	None	Phenol	Ammonia

It is, therefore, of considerable interest to note the procedure put forward by Sokolov, Kirillova and Kupfer.[4] The method is based on observations of the dropping temperature of the plastic, that is, the temperature at which a drop will fall, and, using standardized drying conditions, these research workers claim to be able to manufacture products of constant quality without analysing specimens but by merely controlling the temperature of the resin during drying. So far they have only applied their method to novolacs prepared using hydrochloric acid catalyst (0.3 per cent. of acid, specific gravity 1.19, on the weight of phenol) and constituents in the ratio of 100 parts by weight of phenol to 24, 26 and 28 parts by weight of formaldehyde.

Of the methods of drying studied in the laboratory, two methods, approximating most closely to the industrial processes, received special attention. These were, first, drying in an open copper pot fitted with a stirring mechanism and, secondly, drying in a flask fitted with stirrer. Heating in both cases was carried out by means of an oil bath maintained at a temperature of 170 to 180 degrees C.

The first stage in the drying process occurs at a constant temperature of 99 to 100 degrees C., when water distills off, after which the temperature of the resin gradually rises to the temperature of the oil bath. At the same time, the dropping temperature increases until it reaches a limiting value, known as the "final dropping temperature," which depends, for equal conditions of drying, on the ratio of phenol to formaldehyde. The "final dropping temperature" increases with an increase in the proportion of formaldehyde, as might be expected, and thus the composition of the resin can be directly related to the temperature of drying.

The open method of drying enables the removal of free phenol down to 0.2 per cent. On investigating the properties of the resins, it was found that for comparatively low molecular weight products (with formaldehyde and phenol in the proportion of 24 : 100 and 26 : 100), there is a linear relation between the viscosity of a 50 per cent. alcoholic solution and the dropping temperature of a particular resin. With an increase in the proportion of formaldehyde the viscosity of the resin increases very markedly. The decrease in percentage of free phenol in the open drying process is directly proportional to the increase in dropping temperature. For one and the same dropping temperature the resin prepared with the larger proportion of formaldehyde has the higher phenol content.

When drying in the flask the reverse relation was found to hold. In this method of drying the dropping temperature rises, but the content of free phenol remains unchanged.

[1] A. D. Sokolov, A. V. Kon and N. S. Zarubina, Transactions of the Symposium of the Academy of Sciences of the U.S.S.R. on Organic Chemistry, 1939, p. 91. (In Russian).
[2] A. D. Sokolov and N. S. Zarubina, ibid., p. 153.
[3] A. D. Sokolov and N. S. Zarubina, ibid., p. 167.
[4] A. D. Sokolov, S. I. Kirillova and A. V. Kupfer, ibid., p. 191.

Inquiries and Answers

(In Which is Included General Correspondence)

IMPORTANT NOTICE: If inquirers wish to receive replies by post, a stamped and addressed envelope must be included in their letter. It is understood that the submission of a problem to the Editor permits its publication in this journal.

Availability of Cold Moulding Resin

We have noted with interest your comments in the February issue of *Plastics* on the cold moulding material supplied by this company, arising out of the inquiry received from "Squadron Leader."

We are glad to be able to correct the assumption that "Rockite" cold moulding material is not being made owing to the war. This product is a speciality of Cellomold, Ltd., and as its manufacture does not interfere with the factory's normal programme, we are still able to supply reasonable quantities, subject, of course, to the purpose for which it is used being of sufficient importance as to justify the issue by the Plastics Control of the necessary manufacturing licence.

London. F. A. HUGHES AND CO., LTD.

Bleaching of Cellulose Acetate

I should be glad if you would inform me how cellulose acetate (the unplasticized raw material) can be bleached. The material I have is of a pale yellow colour. J.S.T.

[EDITOR'S NOTE.—Presumably satisfactory results can be obtained by using the method employed in bleaching nitro-cellulose for making high-class colourless celluloid, namely, by treatment with sodium hypochlorite solution or chlorine gas.]

Literature on Tool-room Practice

I am at present engaged in developing a tool-room, where it is hoped eventually to branch out into the manufacture of resin moulding tools. I should be glad if you would kindly inform me where I could obtain all necessary and up-to-date information on the design of plastic moulding dies and relevant technical data.

Bucks. E.L.

[EDITOR'S NOTE.—There is a good section on this subject in *Processes and Machinery in the Plastics Industry* by Brandenburger, and if you can get it, in the Deutsche Jahrbuch fur die *Industrie der Plastischen Massen*, both of which you can see at the Patents Office Library. We hope to publish a series of articles on this subject in the near future.]

Conduit Tubes of Acetate

We have an inquiry for conduit tubes made of black acetate for aircraft; they are bent and curved to various shapes and we understand that straight tube is heated in hot water until soft, then bent roughly to shape and put in a wood (split) former and steam blown through the tube to take out the creases at the bends; then cold water is passed through to set the material. The tubes are from ⅛ in. to 1 in. outside diameter and 40-1,000 in. and 60-1,000 in. thickness and from 1 to 8 ft. long. They are for Air Ministry Priority 1A work.

We should be extremely obliged if you would inform us whether you know of any firm who makes plant suitable for doing this work. S.G.

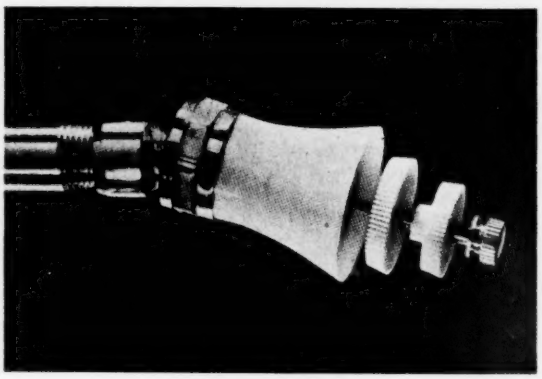
Urea Resin for Plastic Douches

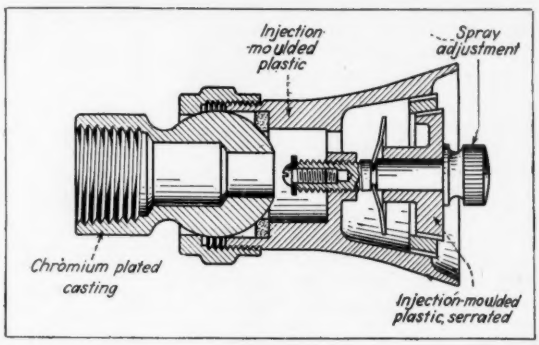
On page 28 of your February, 1941, issue, there is an illustration of a "Douche of urea resin." This kind of rose was manufactured in Germany and we shall be obliged if you would let us know the name of an English manufacturer/s of this resin suitable for the manufacture of such a shower rose. This resin must be impervious to hot water.

WALKER, CROSWELLER AND CO., LTD.

[EDITOR'S NOTE.—What is most interesting is that, judging from results obtained in Germany, as appears from our February note, urea resins can be made to withstand constant contact with water. Application regarding them should be made to British Industrial Plastics, Ltd., and to I.C.I. (Plastics), Ltd.

Yet another type and design is shown in the photograph and drawing below. This spray or douche is made





from Tenite II, a cellulose acetate-butyrate made by Tennessee Eastman Corporation and injection moulded by Thermo-Plastics, Inc., of U.S.A. The plastic is stated to be exceptionally resistant to water.]

Manufacturers of Window Glass Substitute

We are very interested to read the letter of Monolines, Ltd., in the February issue of *Plastics*. We enclose a specimen material in which this company may be interested. We actually produce a type of plastic glass and this mesh has been dipped in what we term "Plastiglass" solution.

UNITED DEVELOPMENT ASSOC.

Bristol. (GT. BRITAIN), LTD.